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Mitigation for Acid Rain Impacts on Atlantic Salmon and Their Habitat

19-20 April 2004
Atlantic Salmon Federation
Conference Center
Chamcook, New Brunswick

**T.L. Marshall[1] (Chair), D. Kircheis[2]
T. Clair[3], and K.A. Rutherford[1]**

[1] Department of Fisheries and Oceans
P.O. Box 1006, Dartmouth, N.S. B2Y 4A2

[2]National Oceanic and Atmospheric
Administration (NOAA)
17 Godfrey Drive, Orono, ME 04473

[3] Environment Canada
P.O. Box 6227, Sackville, N.B. E4L 1G6

Atténuation des effets des pluies acides sur le saumon atlantique et son habitat

Les 19 et 20 avril 2004
Centre de conférences de la
Fédération du saumon atlantique
Chamcook, Nouveau-Brunswick

**T.L. Marshall[1] (Chair), D. Kircheis[2]
T. Clair[3], and K.A. Rutherford[1]**

[1] Ministère des Pêches et des Océans
C. P. 1006, Dartmouth (N.-É.) B2Y 4A2

[2]National Oceanic and Atmospheric
Administration (NOAA)
17 Godfrey Drive, Orono, ME 04473

[3] Environnement Canada
C. P. 6227, Sackville (N.-B.) E4L 1G6

May 2005 / mai 2005

Canada

Foreword

The purpose of these proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or mis-leading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

Avant-propos

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s’est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s’il est clairement indiqué qu’elle l’est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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ABSTRACT

Acid rain, the result of industrial pollutant emissions, negatively impacts the freshwater habitat of Atlantic salmon in eastern Canada and USA. Participants from federal and provincial governments, industry, and NGO's attended a workshop in April 2004 to discuss the causes, effects and mitigation options for acid rain as well as projects currently ongoing or planned for Canada, the USA and Norway.

Liming of watersheds is an important mitigation technique that has been shown to benefit the Atlantic salmon and other terrestrial and aquatic species. It was concluded that a strategy and action plan should be developed to elevate public awareness for building acid rain abatement and mitigation initiatives, and that an ecosystem approach is essential to enable effective action and to build public support groups. Governments need to adopt policy and programs to reduce and eliminate acid rain causing emissions and to support mitigation of the impacts of acid rain.

RÉSUMÉ

Les pluies acides, résultat des émissions de polluants industriels, ont une incidence négative sur l'habitat dulcicole du saumon atlantique situé dans l'Est du Canada et des États-Unis. Des représentants du gouvernement fédéral, des provinces, de l'industrie et d'organismes non gouvernementaux ont participé à une conférence en avril 2004 afin de discuter de la provenance et des effets des pluies acides, des mesures d'atténuation possibles ainsi que des projets déjà en cours ou prévus au Canada, aux États-Unis et en Norvège.

Le chaulage des bassins hydrographiques est une importante technique d'atténuation dont l'effet favorable sur le saumon atlantique et sur d'autres espèces aquatiques et terrestres a déjà été prouvé. Les participants à la conférence ont convenu d'élaborer une stratégie et un plan d'action afin de sensibiliser davantage le public à la nécessité de prendre des mesures de réduction et d'atténuation des pluies acides, et ils ont décidé que l'approche par écosystèmes est essentielle pour que les interventions soient efficaces et pour pouvoir établir des groupes de soutien publics. Les gouvernements doivent adopter des politiques et des programmes d'élimination ou de réduction des émissions qui sont à l'origine des pluies acides et doivent appuyer toutes les mesures prises pour atténuer les incidences négatives des pluies acides.

SUMMARY

- Acid rain, resulting from emission of pollutants from industrial areas of North America, is a serious problem associated with the premature mortality of wild Atlantic salmon and extirpation of some populations.

- Acid rain induces changes to water chemistry, which results in the loss of ions across the salmon's gill epithelium and ultimately, death due to the failure of the circulatory system. Smolt and fry are the most sensitive stages of young salmon. Mortality in salmon is believed to be due to difficulty in transition of juvenile salmon from freshwater to the marine environment.

- Acid rain has adversely affected the survival of threatened and endangered populations of wild Atlantic salmon, especially in the Southern Upland of Nova Scotia (Canada) and in eastern Maine (USA), respectively.

- Liming of watersheds and watercourses is recognized as an acidification mitigation technique that provides benefits to salmon and other species (terrestrial and aquatic), as well as for forestry and agriculture. In Nova Scotia, the Nova Scotia Salmon Association is piloting a river liming mitigation project on the West River, Sheet Harbour. In Maine, NOAA Fisheries is designing a liming project for the Dennys River. Both projects involve several partners.

- There is no clear government policy within Canada and the USA as to the responsible agencies for action to mitigate losses of Atlantic salmon stocks by liming rivers and watersheds in acid rain impacted areas.

- Gene banks offer supportive rearing and breeding to maintain genetic diversity of a salmon population through periods of critically low abundance. Live gene banks can be conducted in designated parts of a river or complete river that still has natural reproducing populations as special refuges, in limed sections of acidified rivers where remnant stocks can sustain themselves or in captivity.

- There are several diverse public interest groups seeking resolution of the problems resulting from acid rain. Governments and the public need to be aware of this and support remedies to address this issue.

- The North American Commission of NASCO may provide this forum to enable discussion of progress on the acid rain issue as it affects salmon, as none other seems to exist, at this time.

The way forward:

- Governments need to adopt policy and programs to reduce and eliminate acid rain causing emissions and to support mitigation of the impacts of acid rain.

- Cooperation among those interested in resolving acid rain issues and partnerships is important to effectively address the problem. It is especially important to further research the ecological impact and cost effectiveness of stream and watershed liming techniques as mitigative measures and to share information and findings among the government, NGO and industry stakeholders.

Government, NGO and industry stakeholder partners should develop a strategy and action plan to elevate pubic awareness to build support for acid rain abatement and mitigation initiatives.

An ecosystem approach to addressing the acid rain issue is essential to enable effective action and to build public support groups.

- Funding needs to be found to support mitigation technologies; preferably in collaboration with those causing the acidic precipitation.

INTRODUCTION

The freshwater habitat of Atlantic salmon within areas of the Maritime Provinces, Nova Scotia in particular, and the State of Maine are mutually and deleteriously impacted by acid rain. Separate federal and state jurisdictions have spent considerable effort in understanding the impacts of acid rain on salmon and exploring the possibilities for mitigation by liming. However, little effort has been accorded by these parties to either the comparison of our separate pilot projects or consultation with externals on the logistics of implementing larger scale programs. This Workshop then was in response to an increasing interest by stakeholders and the governments of Canada and United States, as expressed at the North American Commission (NAC) of the North Atlantic Conservation Organization (NASCO), to consider jointly the causes, effects and in particular, the mitigation options for acid rain.

By agreement between the principal parties, the focus of this Workshop was narrowed to

1. An update on the status of i) acid rain arrestment, ii) water chemistry, and iii) Atlantic salmon in impacted watersheds;
2. The consideration of the current policies, goals, feasibility, experiences, role of government, associated technology of ongoing/planned projects, and scientific context involving liming as a mitigation technique for Atlantic salmon rivers of the NAC Area; and
3. The Scandinavian liming experience in terms of policy, background, programs and successes.

Within this context it was hoped to extract elements essential for consideration in the development of any framework for the mitigation of Atlantic salmon in acid impacted waterways of the Commission Area and, as well, explore the need for/opportunities for continued dialogue between parties within the NAC Area.

Presentations included:

- Policy and role of government in mitigating acidification
- Impact of acid rain on Atlantic salmon and their habitat
- Acid rain update in Canada and US
- Emission trends, current efforts to reduce acid rain in Canada and US and projects for recovery
- Summary of approaches to mitigation in published North American work
- The Scandinavian experience: philosophy, policies, major programs, successes and problems
- Approaches to prioritizing acid-impacted salmon populations for recovery initiatives
- Mitigation: summary/overview of recent/current and planned projects; their objectives/results and conclusions re the potential for mitigation

Workshop participants are listed in Appendix 1. The letter of invitation and tentative agenda appear as Appendix 2 and 3, respectively. Background documents or summaries made available at the workshop but which were not formally presented appear in Appendicles 4-6.
The Workshop Organizing Committee consisted of Larry Marshall and Shayne McQuaid, DFO, Tom Clair, Environment Canada, Dan Kircheis, NOAA, and Stephen Chase, then of the Atlantic Salmon Federation.

Policy and Role of Government in Mitigating Acidification

a) Maine – Overview by Dan Kircheis

- No real 'policy' in the U.S.A.
- The Maine policy on clean water prior to 2004 did not have any provisions that would allow for us to apply calcium carbonate for the purpose of salmon restoration. The following changes were made in an effort to accommodate the proposed liming project:

  An Act to Amend Water Quality Laws to Aid in Atlantic Salmon Restoration.

  38 M.R.S.A § 465. 1. C. is amended to read:

  C. There may be no direct discharge of pollutants to Class AA waters, except storm water discharges that are in compliance with state and local requirements. <u>A discharge for the purpose of restoring waters to their historic natural quality is allowed if approved by the department.</u>

  38 M.R.S.A § 465. 2. C. is amended to read:

  C. Direct discharges to these waters licensed after January 1, 1986, are permitted only if, in addition to satisfying all the requirements of this article, the discharged effluent will be equal to or better than the existing water quality of the receiving waters. <u>A discharge for the purpose of restoring waters to their historic natural quality is allowed and is not required to be equal to or better than the existing water quality of the receiving waters.</u> Prior to issuing a discharge license, the department shall require the applicant to objectively demonstrate to the department's satisfaction that the discharge is necessary and that there are no other reasonable alternatives available. Discharges into waters of this classification licensed prior to January 1, 1986, are allowed to continue until practical alternatives exist. There may be no deposits of any material on the banks of these waters in any manner so that transfer of pollutants into the waters is likely<u>, except for the purpose of restoring the historic natural quality of the waters if approved by the department</u>.

- monitoring of permits is the responsibility of the U.S. Environmental Protection Agency (EPA)
- EPA does not have a nation-wide policy, at least in the context of mitigating acid rain (policies for mitigating acidification resultant of mining is a separate issue)

b) Canada – Overview by Tom Clair

- Currently no policy for mitigation in Canada
- Ownership of the issue in one form or another is shared by Environment Canada, Fisheries and Oceans Canada, perhaps Natural Resources Canada and Provincial Governments
- Permitting for client-led liming of watercourses is currently authorized by DFO Oceans and Habitat Branch and Environment Canada Environmental Impact Review process
- In 2005-06, Environment Canada will work with partners to produce working papers which will provide guidance on the technical, scientific, economic and policy aspects of acidification mitigation and will support a workshop where these will be discussed with all interested parties.

Presentation by Clair/Timoffee by the same title follows.

Policy and Role of Government – Tom Clair/Kerri Timoffee

Slide 1

Policy & Role of Government in Mitigating Acidification

Workshop on Mitigation for Acid Rain Impacts on Atlantic Salmon and their Habitat / April 19, 2004

Tom Clair / Kerri Timoffee

Slide 2

Outline

- Canada's early approach
- Current program
- Progress
- Next Steps

Slide 3

Canada's Early Approach

- Scientific evidence drove policy
- Abatement in Ontario in 1968
  - emission reductions & taller stack
- Recognition of need to reduce emissions
- "target load" developed
- International negotiations
- *Responsive approach*

Slide 4

Canada's Early Approach
Eastern Canada Acid Rain Program

- Comprehensive program launched in 1985
- Goal to protect moderately sensitive aquatic ecosystems
- Aim to reduce emissions by 40% from 1980
- *Harmonised approach*

Slide 5

Canada's Early Approach
Role of Federal Government

- Negotiate reductions in transboundary emissions from US
- Research and monitoring
- Financial support for development of technologies for industry

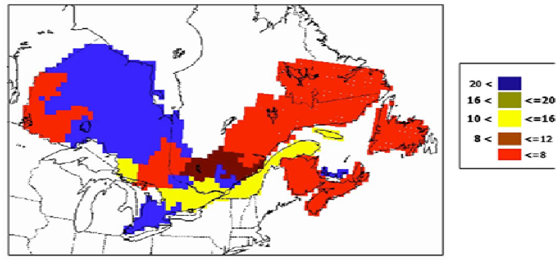
Slide 6

Canada's Early Approach
Role of Provinces

- Control emissions from point sources
  - Focus on regulating large sources, e.g., power plants, smelters
- Participate in acid rain effects research, monitoring
- Financial support for development of technologies for industry

Slide 7

Current Goal – Reduce Deposition to below Critical Loads



Critical load values (kg/ha/yr) of sulphate in precipitation

Slide 8

Canada's Current Program – Post-2000 Acid Rain Strategy

- Signed by 26 federal/provincial/territorial Energy and Environment Ministers
- Main elements
  - Reduce SO^2 emissions in eastern Canada and the US
  - Prevent pollution and keep clean areas clean
  - Maintain an adequate acid rain science and monitoring program
  - Annual reporting

Slide 9

Strategy Implementation

- Review of acid rain science programs in Canada
- Continued provincial and federal science and monitoring
- New provincial targets for further SO^2 reductions

Slide 10

Next Steps

- Contribute to discussions with US regarding further emission reductions
- Initiate discussions with western provinces

Slide 11

Summary

- Science-driven policy
- Emission abatement focus
- Harmonized approach between governments

Impact of Acid Rain on Atlantic Salmon and Their Habitat

a) Maine – Dan Kircheis

- Provides update on status; downeast rivers are 'endangered'; others, excluding the Penobscot River, are also on the brink of extirpation
- Water chemistry is now being recognized as a factor that may likely be limiting the recovery of Atlantic salmon in Maine
- Norm for pH is >6.0, some rivers are low pH 5's, and the odd tributary may be slightly <pH 5
- Aluminum complexed on organic acids is a moderate stress factor, and pH is seen to compromise survival of smolts on entry to salt water, especially on episodic events
- Provided background (Appendix 4) 'Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990'

b) Nova Scotia Southern Upland – Peter Amiro

Slide 1

Status of Wild Atlantic Salmon, on the Southern Upland of Nova Scotia

Peter G. Amiro
Diadromous Fish Division
DFO

The status of wild Atlantic salmon on the Atlantic coast of Nova Scotia is assessed in two Salmon Fishing Areas (SFAs):

- SFA 20 Eastern Shore
- SFA 21 South Shore

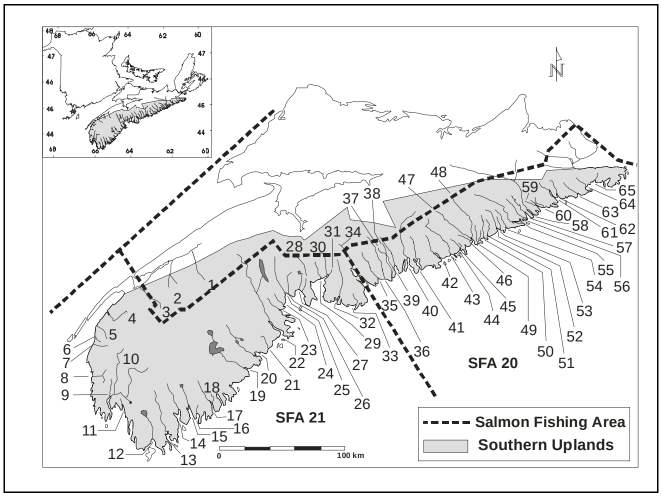
Slide 2

Salmon Fishing Areas 20 &21 Southern Upland

- Counts at fishways and population estimates.
- Stock and recruitment trends in non acidified areas.
- Return rates of hatchery smolts non-acidified and acidified areas.
- Juvenile salmon densities as indicators of status.
- Prognosis based on acid rain and low marine survival (ASRAM).
- Results of electrofishing cruise of the SU in 2000.
- 65 rivers, 30 with pH <5.0 as of 1986…improving???

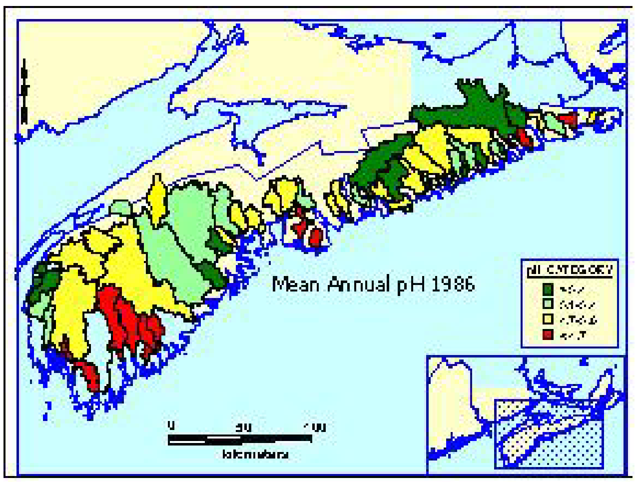
How stocks were assessed in SFA 20 and 21.

Slide 3



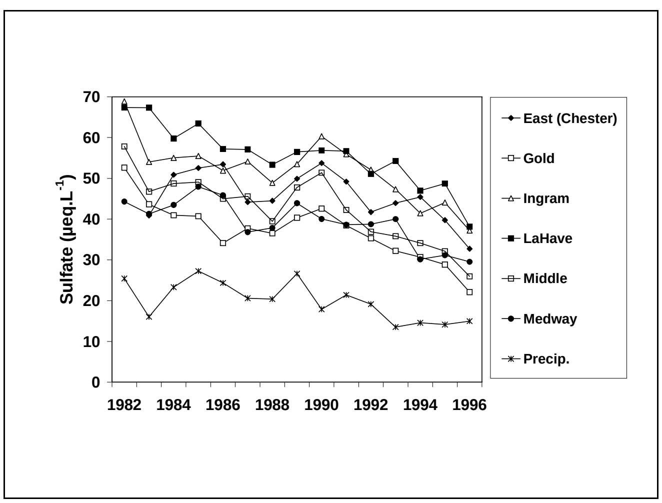
Location of the 65 rivers of the Southern Upland of Nova Scotia.

Slide 4



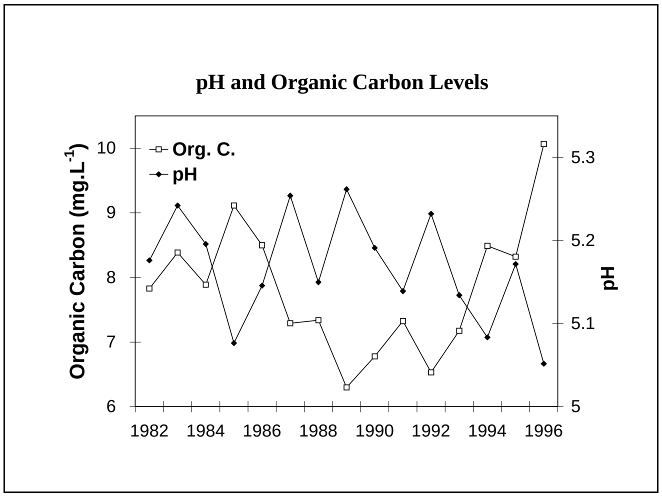
Graphic presentation of the drainage areas of rivers on the Southern Upland of Nova Scotia categorized by their mean annual pHs as determined in 1986.

Slide 5



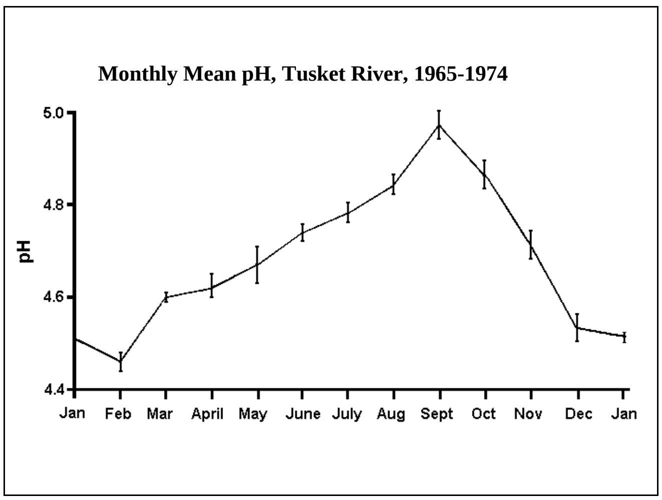
Trends in annual sulphate levels determined from water samples obtained from six rivers of the Southern Upland of Nova Scotia and from precipitation 1982 to 1996.

Slide 6



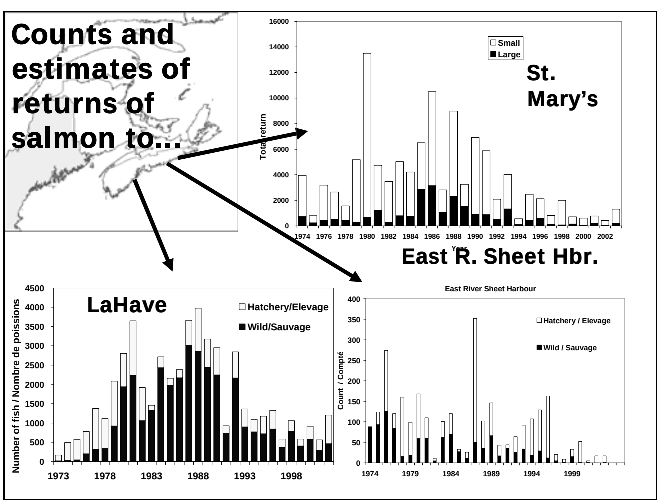
The inverse relationship between pH and organic carbon is indicative of a loss in the acid neutralizing capacity in soils of the Southern Upland. These soils have been stripped through acute acid precipitation. Cations, like calcium, that buffer acids and provide essential elements for salmon growth and survival, are no longer available in sufficient quantity. The recovery of these essential cations will be slow, perhaps in the order of 30 to 50 years.

Slide 7



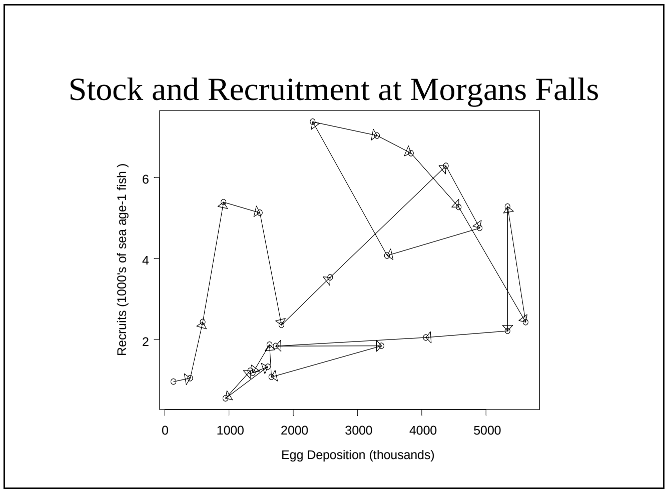
Typical annual pattern of pH as represented by Tusket River monthly mean pH, 1965 to 1974.

Slide 8



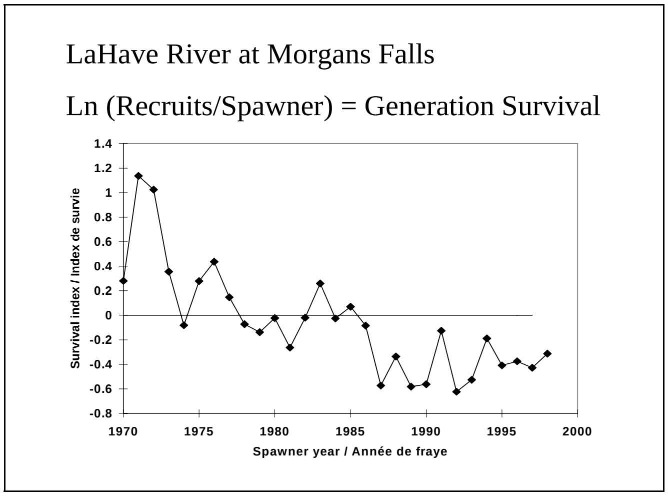
Records of annual counts of Atlantic salmon at three monitoring sites on the Southern Upland for the period 1973 to 2000.

Slide 9



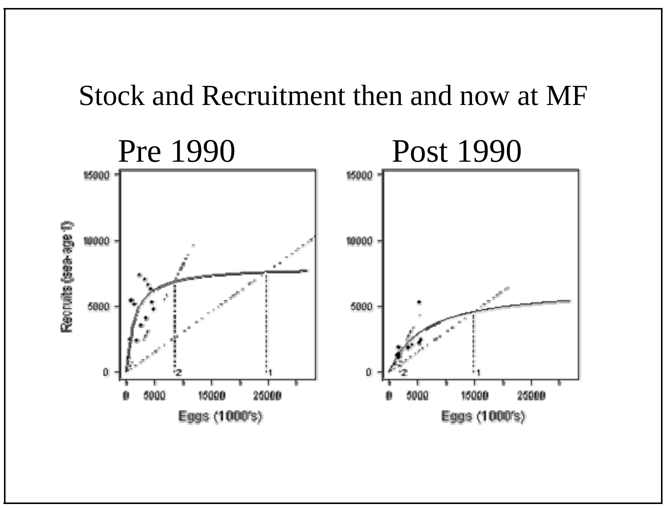
The number of recruits (returning salmon) at Morgans Falls shows two levels of response. Pre 1990 and post 1990 as indicated in the trace pattern.

Slide 10



This effect is also shown in the Ln of Recruits/Spawning salmon above Morgans Falls. The shift seems to have been extreme in the 1987 spawning class which is the 1991 one sea winter return.

Slide 11



This translates into two different stock and recruitment curves for the population above Morgans Falls, pre 1990 and post 1990. The diagonal lines are the replacement population lines for recruit salmon and for recruit salmon plus repeat spawning salmon. Note that post 1990 the line for recruit salmon does not cross the curve i.e. the population will not likely persist. This is problematic because the repeat spawning component at Morgans Falls has fallen from a mean of about 14% to less than 4%.

Slide 12

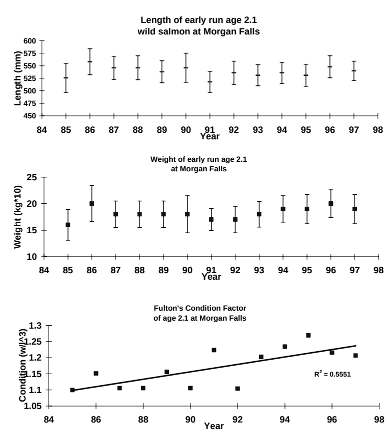
Wild salmon persistence above MF?

- Wild smolt to adult (1SW+2SW) return = 3.57% (1996 to 2003)
- Therefore required production is = (1/.0357) = 28 smolts/spawning fish
- Observed smolt per spawner = 11.4 (4.7 to 17.3)
- At that productivity the required marine survival would be 8.7%.
- Historic (pre 1985) marine survival of wild salmon was about 10% after fisheries.

Slide 13

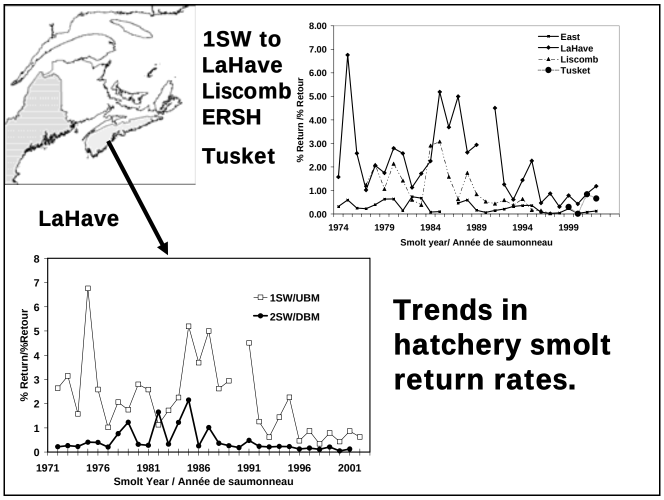
Has the condition of the fish changed?

Slide 14



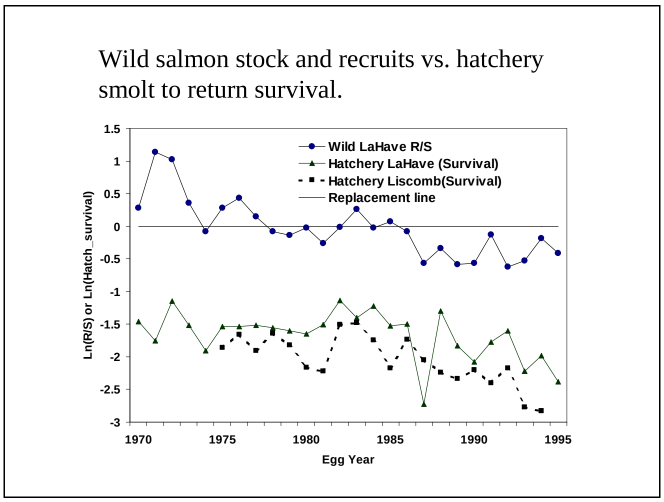
Trends and annual variation in length, weight, and condition of wild aged, two-year freshwater smolts returned after one sea winter to Morgans Falls on the LaHave River before August.

Slide 15



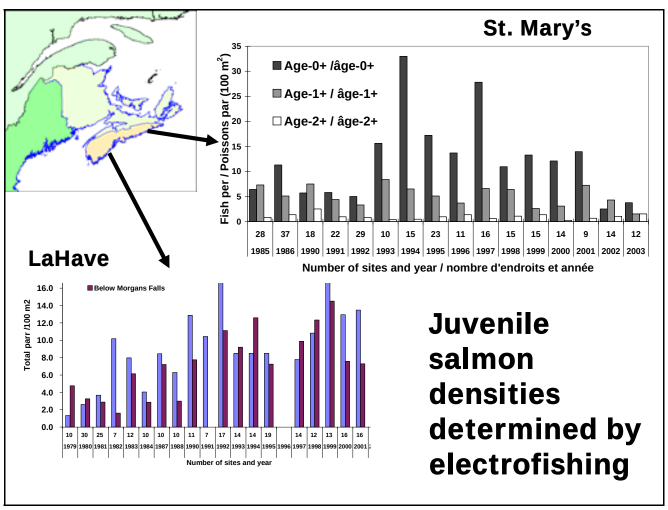
Trends in hatchery smolt return rates after one sea winter to the LaHave, Liscomb and East River Sheet Harbour and after one and two sea winters to Morgans Falls, LaHave River.

Slide 16



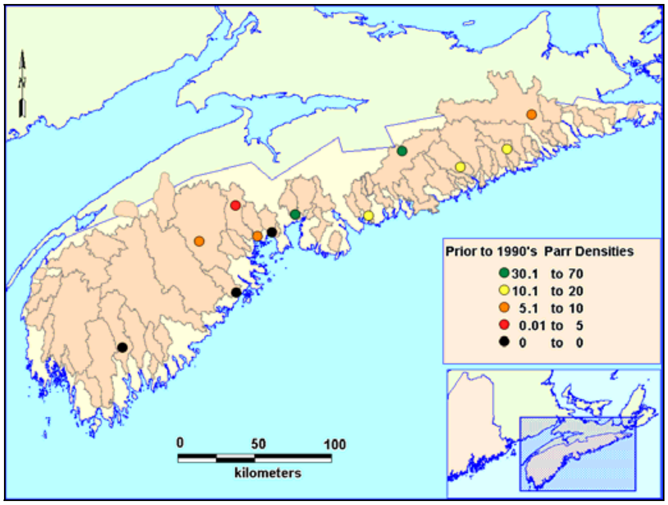
Comparison of LnR/S to the logarithm of survival of hatchery stocked smolts aligned by egg year for native origin hatchery smolts stocked, released, and returned to the LaHave and Liscomb rivers. This indicates a similar response in wild and hatchery survival despite the potential dependence effects in the wild stock and recruitment relationship.

Slide 17



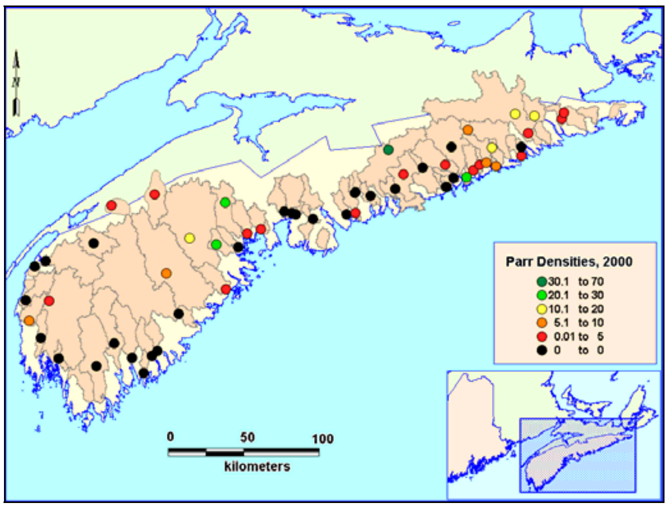
Juvenile Atlantic salmon densities, per 100 m^2, determined at standard electrofishing locations in the St. Mary's River, 1985 to 2000 and LaHave River 1979 to 2000.

Slide 18



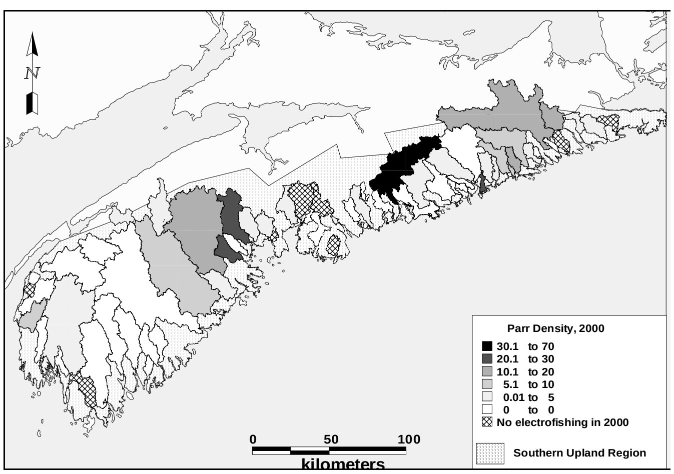
Spatial distribution and quantitative categorization of the densities (per 100 m^2) of juvenile Atlantic salmon determined by electrofishing in rivers of the Southern Upland of Nova Scotia prior to 1990.

Slide 19



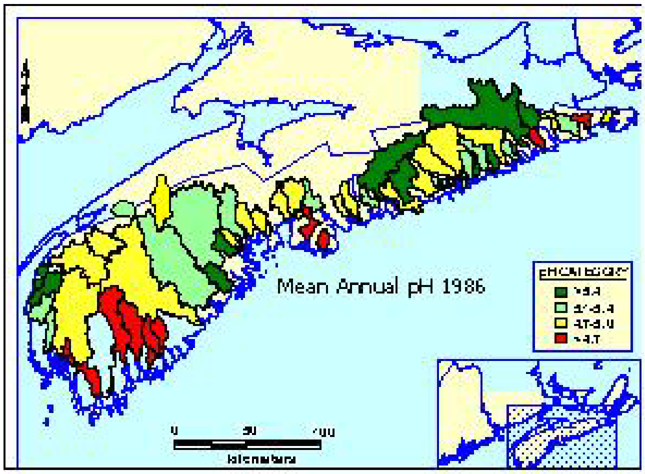
Spatial distribution and quantitative categorization of the densities (per 100 m^2) of juvenile Atlantic salmon determined by electrofishing in rivers of the Southern Upland of Nova Scotia in 2000. Note the prevalence of black dots where no salmon parr were found. This occurred in 49% of the 57drainages examined.

Slide 20



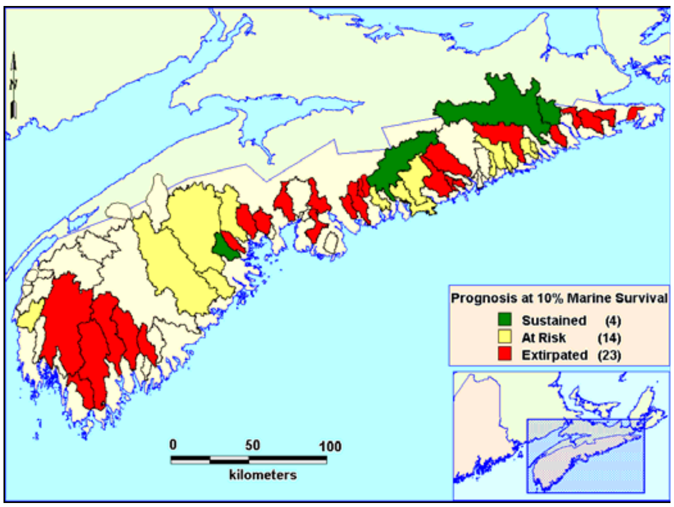
This is the same data but presented by drainage area and gives a better perspective of the extent of the decline.

Slide 21



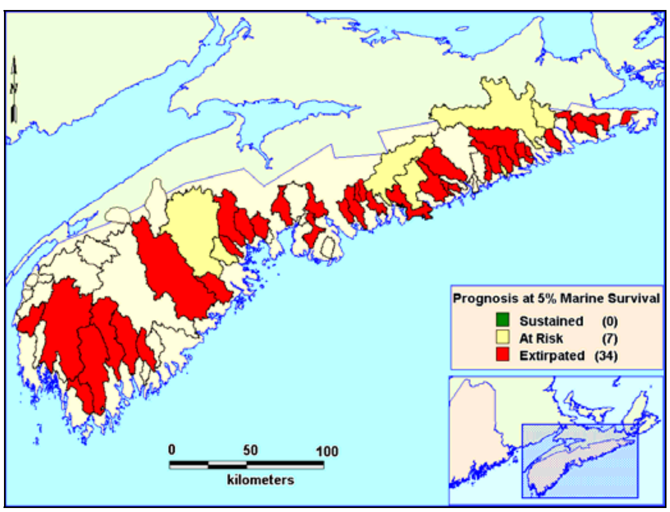
Graphic presentation of the drainage areas of rivers on the Southern Upland of Nova Scotia categorized by their mean annual pHs as determined in 1986.

Slide 22



Prognosis determined by population simulation by the Atlantic Salmon Regional Acidification Model for the sustainability of Atlantic salmon in rivers of the Southern Upland of Nova Scotia. Simulations were made assuming 20% marine survival.

Slide 23



Prognosis determined by population simulation by the Atlantic Salmon Regional Acidification Model for the sustainability of Atlantic salmon in rivers of the Southern Upland of Nova Scotia. Simulations were made assuming 5% marine survival.

Slide 24

The bottom line is...

- Decline in recruitment is wide-ranging despite closures in fisheries.
- Extirpations likely in about 85% of the rivers of the SU within three generations.
- As of 2000 about 50% had extirpated and numbers of vulnerable populations are increasing i.e Medway.
- Rivers which are not significantly impacted by acid rain may not persist.

The synopsis.

Slide 25

Why the decline?

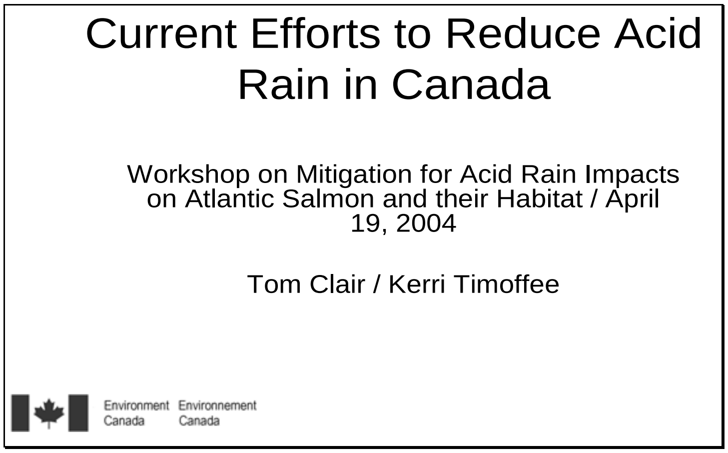
- Ecological change in the North Atlantic. E.g regime shift, temperatures, predators, aquaculture escapes and their interactions.
- Chemical impacts including UVB, endocrine disrupters, chemical fallout and residual effects from freshwater stages.
- Local affects add to the variation but cannot account for the general decline e.g. acid rain, most predators, point source pollution.

The possible causes.

Emission Trends, Current Efforts to Reduce Acid Rain

a) Canada – Tom Clair/Kerri Timoffee

Slide 1



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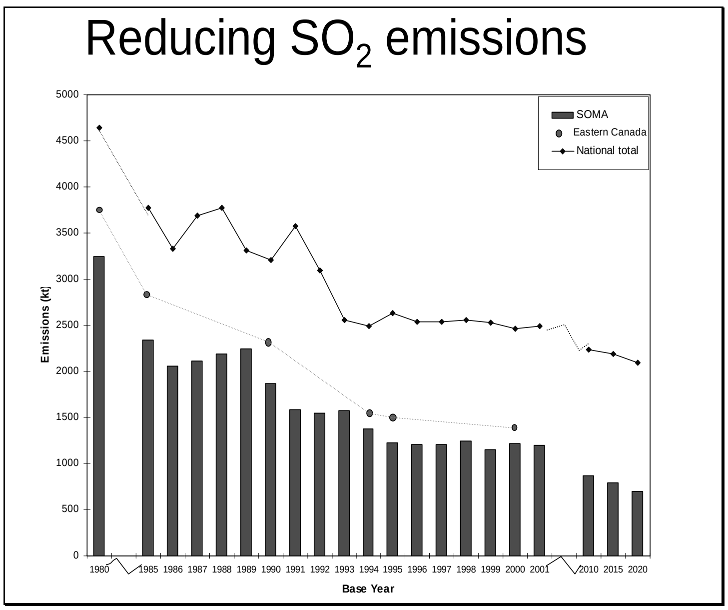


Canada has made considerable progress in reducing SO2 emissions. Lines on the graph reflect the various targets for the 3 main programs in Canada

1985 Eastern Canada Acid Rain Program & First Sulphur Protocol under LRTAP, established caps to be achieved by Dec 1993

eastern Canada cap of 2.3 M tonnes (**green**)

graph clearly shows that the provinces did more than required under the ECARP

national cap of 3.2 million tonnes (**blue**)

1991 Canada - US Air Quality Agreement

extended both caps to 2000, making the national cap permanent

1994 Second Sulphur Protocol under LRTAP - SOMA cap of 1.75 M tonnes by 2000 (**burgundy**)

1999 protocol to abate acidification, eutrophication and GLO under LRTAP

multi-effect, multi-pollutant SO_2, NO_X and VOC reduction commitments from domestic programs [looking into ratification for 2003 or 2004]

In 2000, national SO_2 emissions = 2.5 M tonnes (20% below cap)

eastern Canada emissions = 1.6 M tonnes (29% below cap)

SOMA emissions = 1.2 M tonnes (33% below cap)

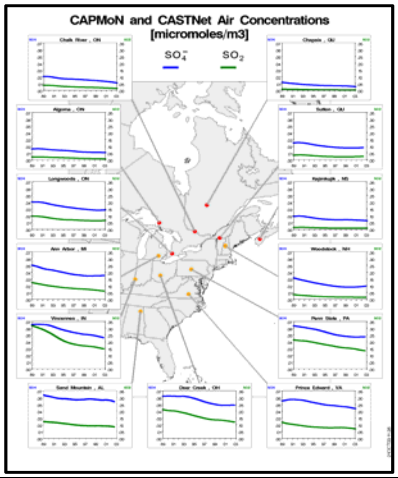
EXTRA - not part of this graph - **for NOX**

1988 LRTAP Protocol on NOX reductions stablise NO_X emissions

1991 Canada - US Air Quality Agreement also introducd NO_X commitment, to reduce stationary source NO_X emissions by 100,000 tonnes below forecast levels by.

Slide 3

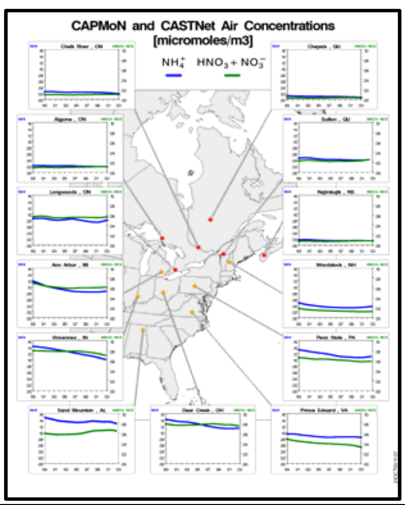
Time Series –
CAPMoN and CASTNet Networks



Definite decrease in SO2 and SO4 in air in the 1990s
Definite decrease in SO4 in precipitation in the 1990s

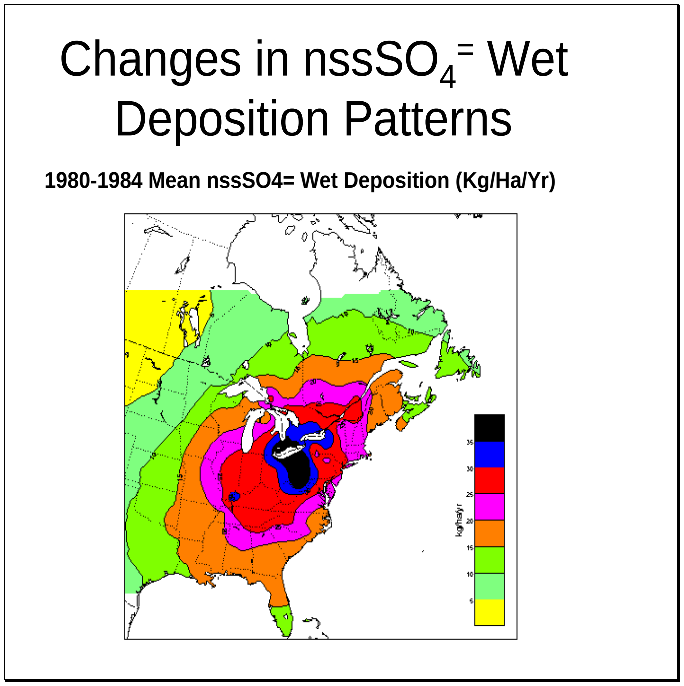
Slide 4

Time Series –
CAPMoN and CASTNet Networks



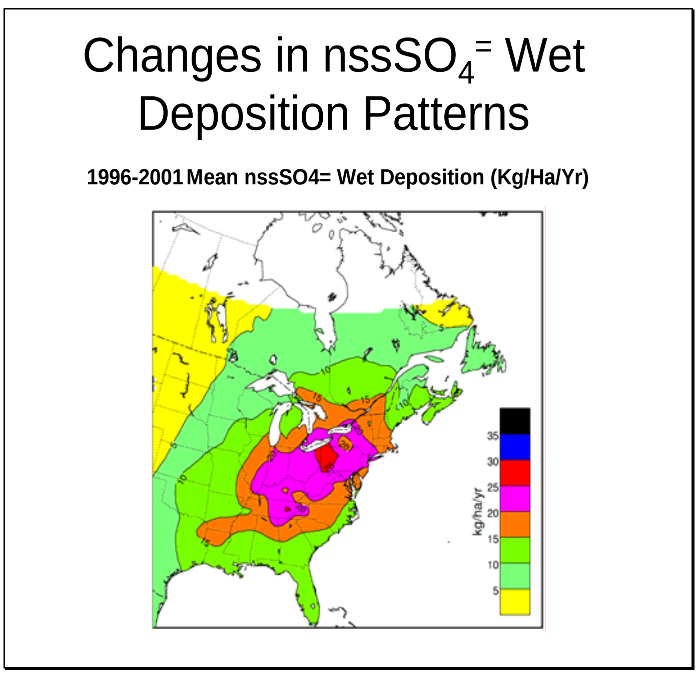
No decrease of NO3- in air or precipitation

Slide 5



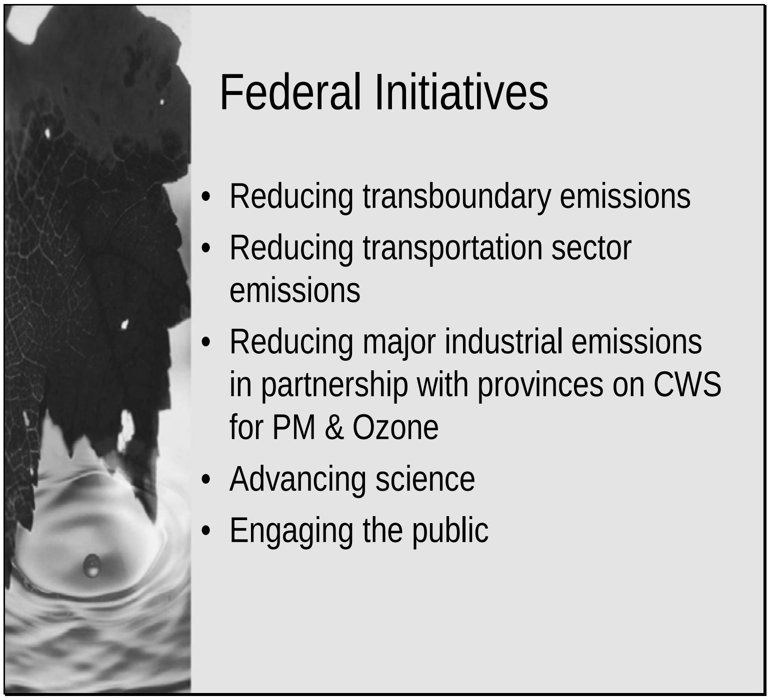
The following two deposition maps illustrating that the amount of sulphate in precipitation has declined substantially in eastern North America over the last 20 years.

Slide 6



Sulphate declines are due to emission reductions in Canada and the U.S.

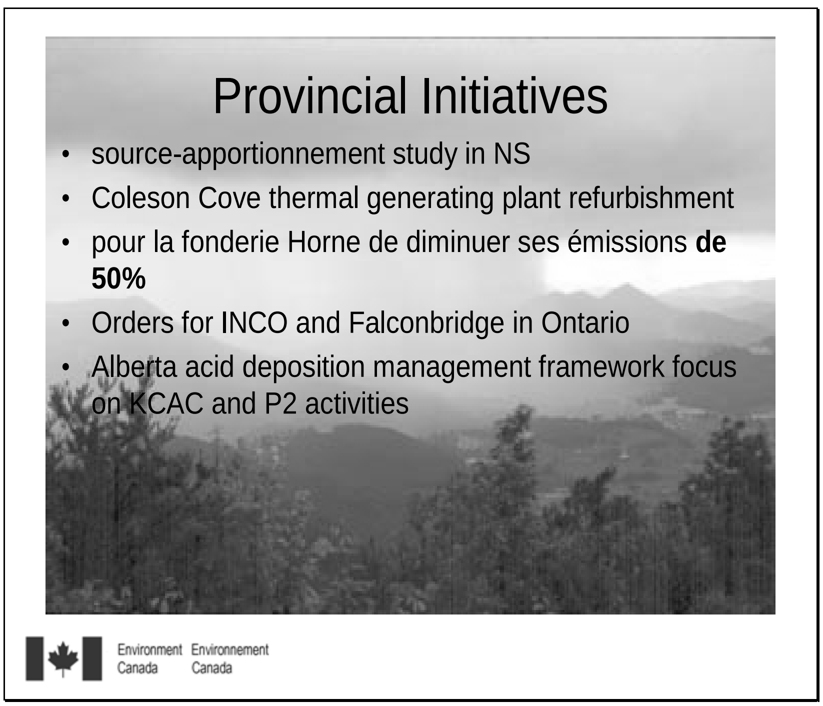
Slide 7



Ten-year Clean Air Agenda

Continued science and monitoring program to assess the degree of environmental improvement achieved and the adequacy of control programs: are targets being met (emissions inventories); are they having the desired effect (deposition monitoring and biological effects monitoring); are further controls required?

Slide 8



Examples of initiatives in eastern Canada that provinces are taking to reduce SO_2 and NO_X

In **NS**

- currently engaged in a study to determine the contribution that major emission sources make to acid deposition. Together with SO2 dispersion modelling, the study will provide estimates of sulphate and nitrate deposition from all major sources which affect NS. Info will be used to guide the Energy Strategy emission reduction commitments.
- Plan to amend provincial Air Quality regulations

In **NB**

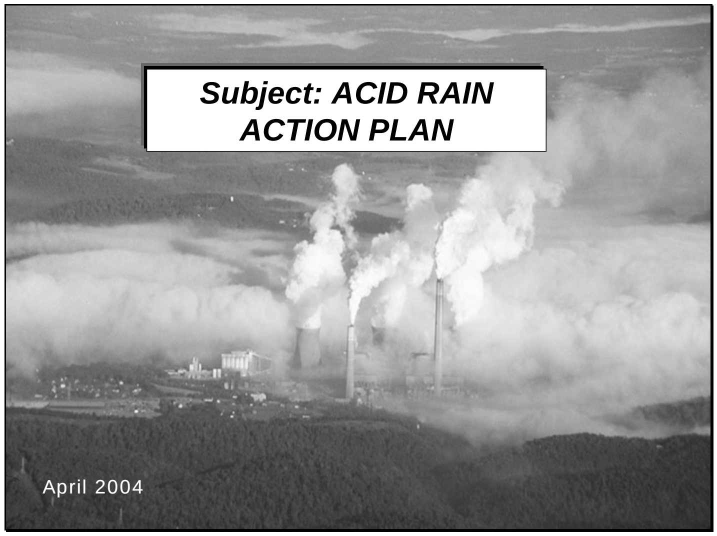
refurbishment - conversion to Orimulsion fuel and addition of extensive emission control equipment and new burner configuration; reduce emission rates of SO_2, NO_X and PM by 77%, 70% and 75% respectively by 2004

In **ON**

Clean Air Orders for INCO and Falconbridge (Sudbury Operations) required to reduce allowable ground-level concentrations of SO_2 from 0.5 ppm to 0.34 ppm; also reduce allowable limits of annual SO_2 emissions by 34% after Dec 2006

b) Atlantic Salmon Federation – Stephen Chase

Slide 1



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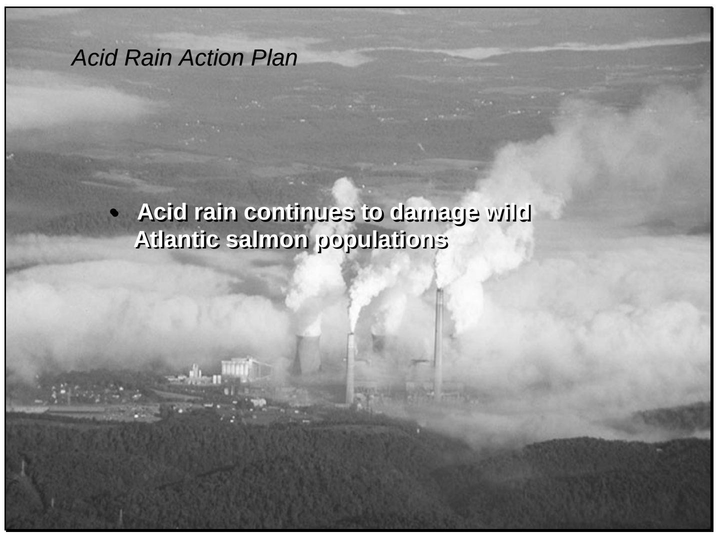

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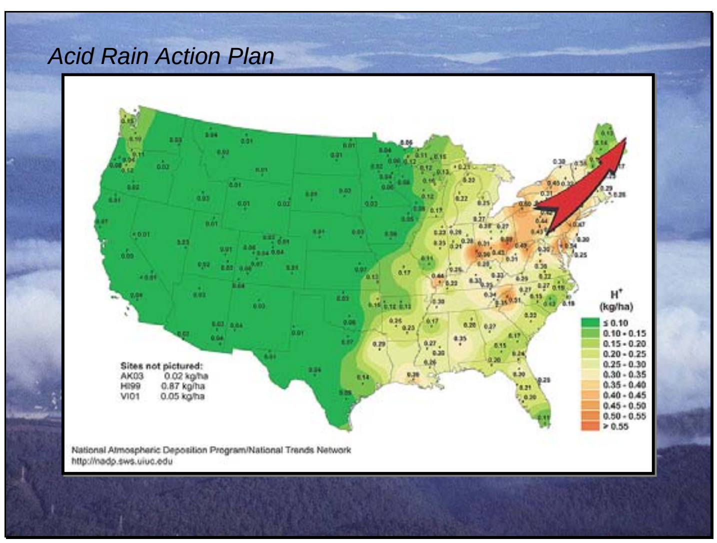
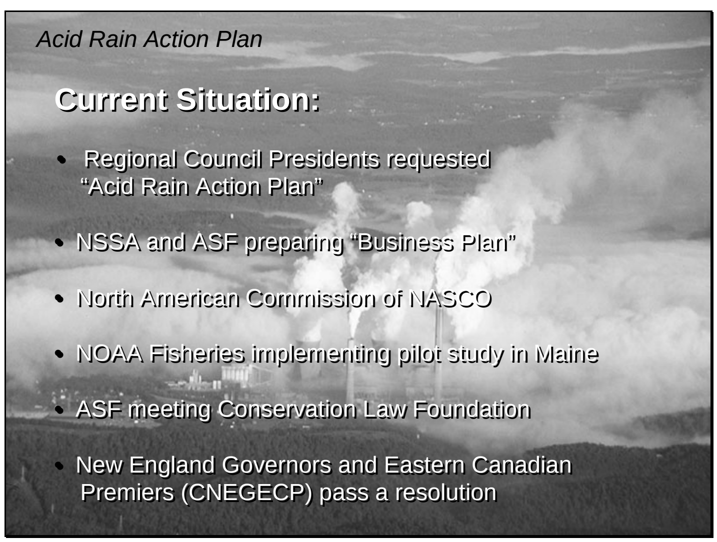


Slide 4

Slide 5

Slide 6



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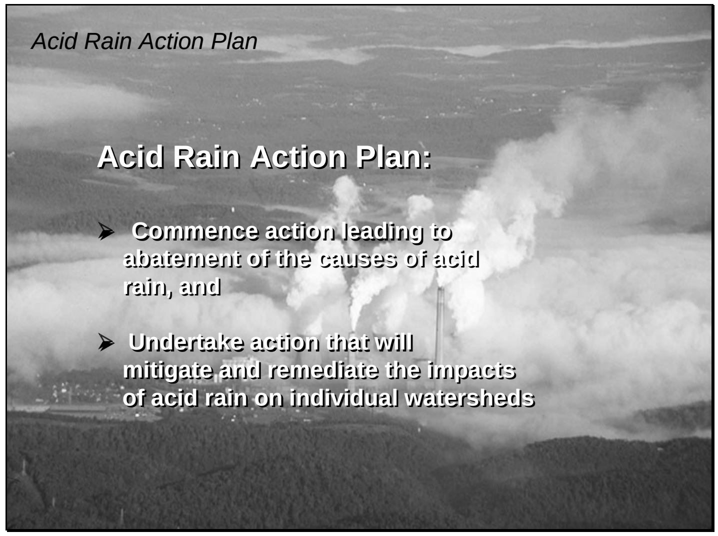

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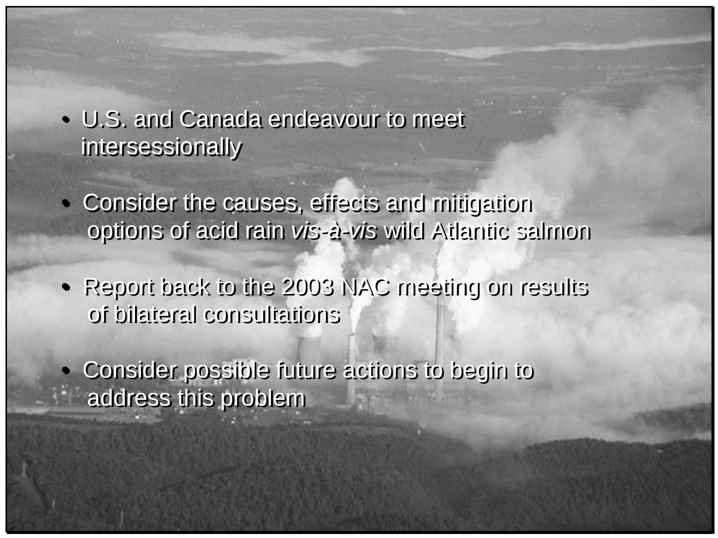

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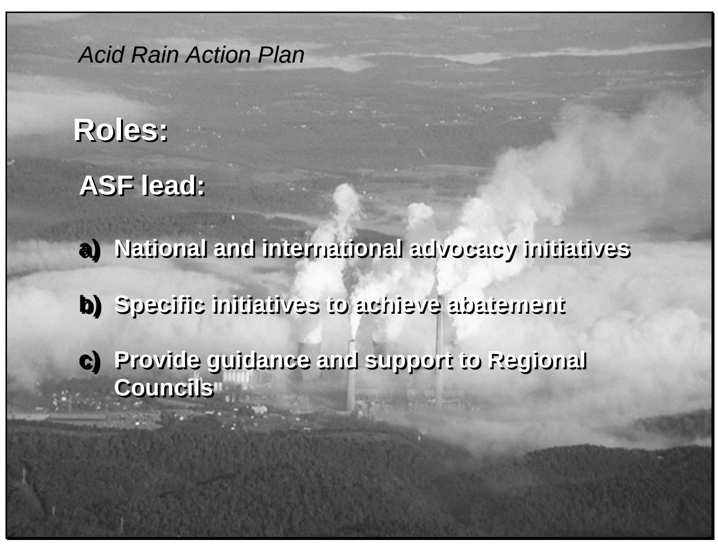

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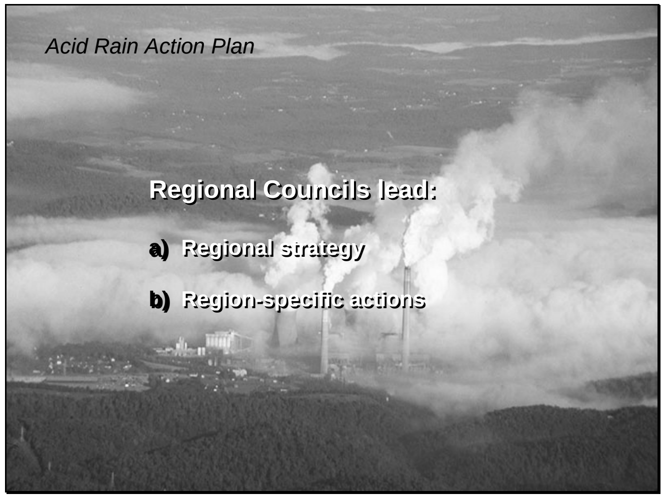

Acid Rain Action Plan
Regional Councils lead:
a) Regional strategy
b) Region-specific actions

c) Water Chemistry Trends in Maine – Richard Dill for Steve Kahl

Slide 1

Water Chemistry in Maine Atlantic Salmon Rivers

Slide 2

General Overview

- Maine – Largest number low alkalinity waters in Northeastern US
- Characteristically thin and naturally acidic soils, providing very little buffering capacity
- However…less than 5% Maine waters chronically acidic (Studies by EPA 1980's, UM 1990's)

Slide 3

General Overview *con't*

- Maine salmon rivers experience episodic depressions in pH and related water chemistry generally during spring and fall (high flow events)
- Past Water Chemistry Studies….pH's below 6.0 documented in most Downeast rivers, as low as 5.0 on some rivers such as the Pleasant, and near or below 5.0 on tributaries
- Generally though, base flow pH related water chemistry in Maine salmon rivers is relatively healthy for salmon (pH >6.0)

Slide 4

What is causing pH depressions in Maine Salmon Rivers?

- Natural and Anthropogenic Causes
- *Natural*
  - Dilution of base cations during high discharge events.
  - Naturally occurring organic acidity
  - Salt effect driven by marine aerosols (excess neutral salts displace
- *Anthropogenic*
  - Primarily industrial emissions of sulfur dioxides (SO^2), nitrogen oxides (No_x), ammonia (NH_3) in the West carried by prevailing winds to the East

Slide 5

Regional Water Chemistry Trends

- Stream water pH and ANC up slightly, although less so in Maine downeast rivers
- 1970 & 1990 amendments to Clean Air Acts.

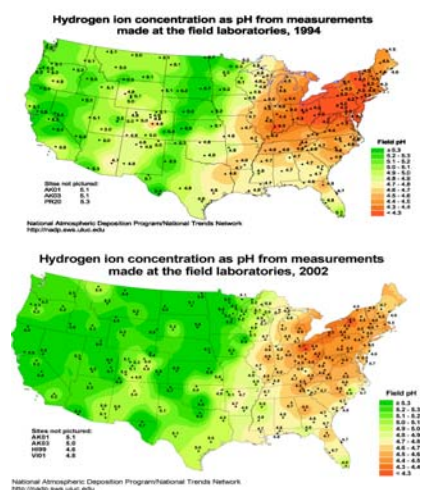
  Result = Reduction in sulfate emissions (million metric tons, TON) *Driscoll et al. 2001*

  1900 = 9 TON

  1973 = 28.8 TON

  1998 = 17.8 TON

Slide 6



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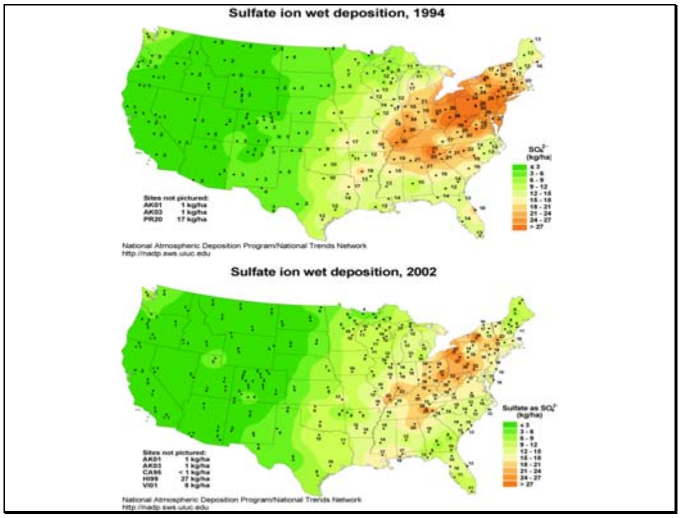


Slide 8

Trends *con't*

- Regionally Aluminum and Calcium both down (inversely related to pH)
- DOC increasing everywhere…. *Kahl 2004, personal communication (NEGECP)*
- Even though precipitation pH increasing from ~ 4.6 to 4.8
  - Benefits to surface water pH from increasing precipitation pH could be offset by increasing DOC (natural organic

Slide 9

Base Flow Water Chemistry Data in Maine Salmon Rivers

- pH generally > 6.5
- Ca range 2+ to 3+ mg/L
  - Higher in Penobscot and rivers west
- Dissolved Al < 100µg/L
- Inorganic aluminum ?????????

Slide 10

2002 Storm Water Data

(M. Whiting, ME DEP)

- Winter/Spring 2002 storm/snow melt water chemistry downeast salmon rivers (NG, PL, EM, MC, Tunk), 5 or 6 storms
- pH ranged 5.5-6.5 (in most instances near or below 6.0 during storms/melt events)
- Ca ranged 1.11 – 2.49 mg/L
- Dissolved Aluminum 111-241 µg/L
- Inorganic Aluminum = generally 20-30's µg/L on most rivers (only sporadic data)
  - up to 50's µg/L on Pleasant and Tunk

Slide 11

2003 Maine Salmon Rivers "pH Survey"

- ~ 67 sites in 12 salmon drainages
- Spring, Summer, Fall
- 2 to 4 mainstem sites and multiple tributaries per river system
- All sites sampled in same 8 hour period
- ClpH, EqpH, ANC (µeq/L), Conductivity (µS/cm), Color (PCU

Slide 12

2003 "pH Survey" Summary

- Observed spring and fall pH depressions associated with high flow events
- Rivers east of Penobscot lower pH and ANC than rivers west
- Tributaries lower pH than the mainstems

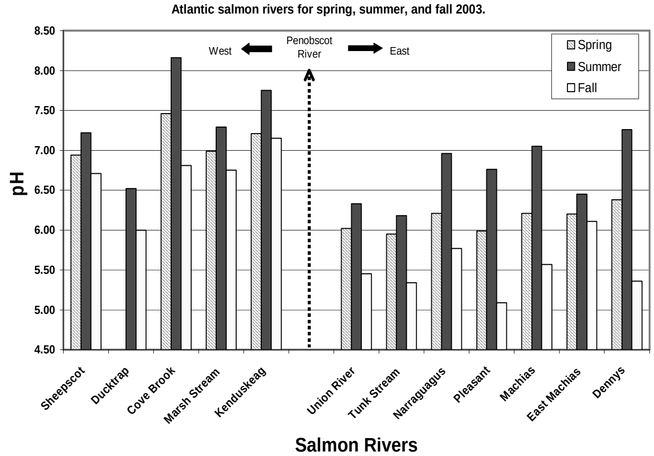
Slide 13

"pH Survey" *con't*

- Lowest pH's occurred in fall (Oct. 28th)
- Rivers East of Penobscot River
  - 17 of 21 mainstem sites and 29 of 32 tributaries below pH 6.0
  - 9 tributary sites below pH 5.0
- In addition to dilution of base cations by high flow, DOC probably playing a major role in depression of pH

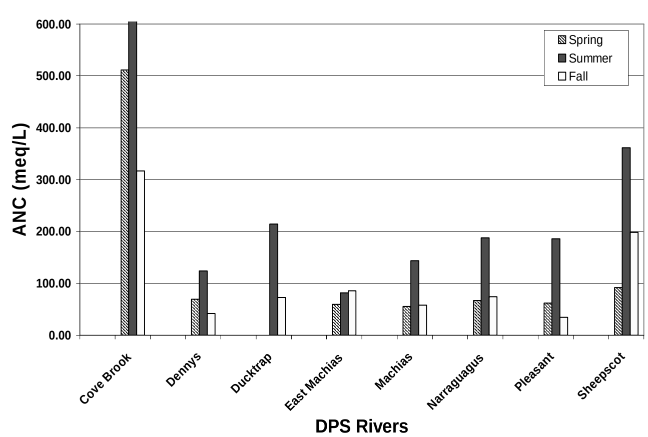
Slide 14

Figure 5.1 Comparison of pH measurements for the lowermost mainstem site for 12 Maine Atlantic salmon rivers for spring, summer, and fall 2003.



Slide 15

Figure 5.2. Comparison of acid neutralizing capacity (ANC) from the lowermost site for the 8 DPS salmon rivers for spring, summer, and fall 2003.



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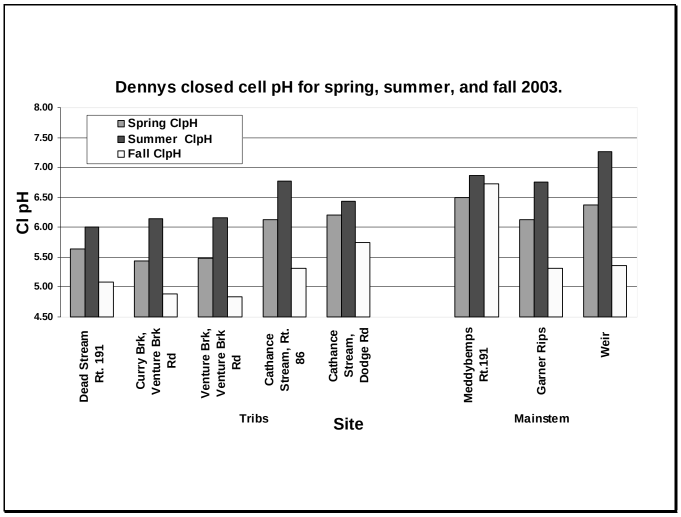
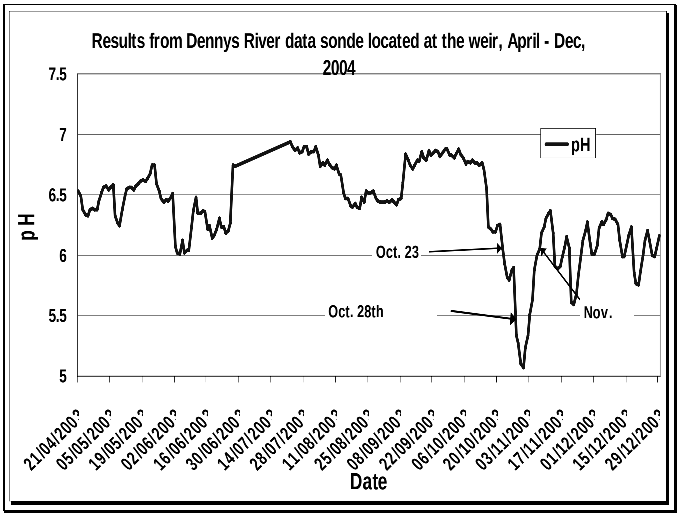


Dennys River pH Survey, 2003

Slide 17



Slide 18

Are fall pH depressions having an affect on large parr survival??

Overwinter Survival			
Smolt Year	Parr	Smolts	Overwinter S
1996	11,035	**2,813**	25.5%
1997	10,529	**2,871**	27.3%
1998	25,137	**2,925**	11.6%
1999	21,133	**3,607**	17.1%

Slide 19

2004 Water Quality Monitoring Activity in Maine Salmon Rivers

- 2004 pH Survey (13 Drainages, ~ 70 sites)
- Dennys River WQ Survey
- CEDAR – Dennys, Cathance, Pleasant
- Spring Smolt Run Weekly WQ sampling (6 weeks)
- Data Sondes (Dennys, Narraguagus, Pleasant)
- USGS Hydrology Study (Dennys + Tributaries)

d) To Lime or Not To Lime – Tom Clair

Slide 1

To lime or not to lime
What's the question again?

Tom Clair
Environment Canada – Atlantic Region
Sackville, NB

Slide 2

Purpose of the talk

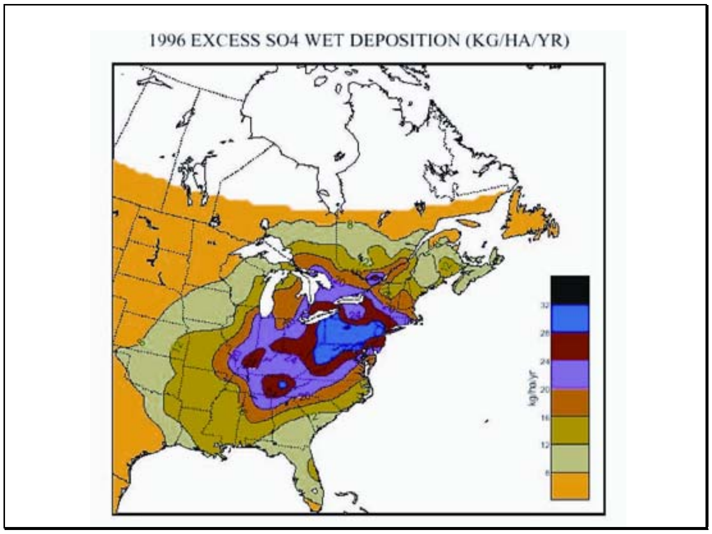
- To demonstrate how future changes in acid deposition will affect the chemistry of surface waters in Atlantic Canada
- To show currently used liming methods in Europe and North America
- To discuss the policy situation in North America regarding the mitigation of ecosystems

Slide 3

Why is Atlantic Canada so affected by acid rain?

- Location, geology and climate

Slide 4



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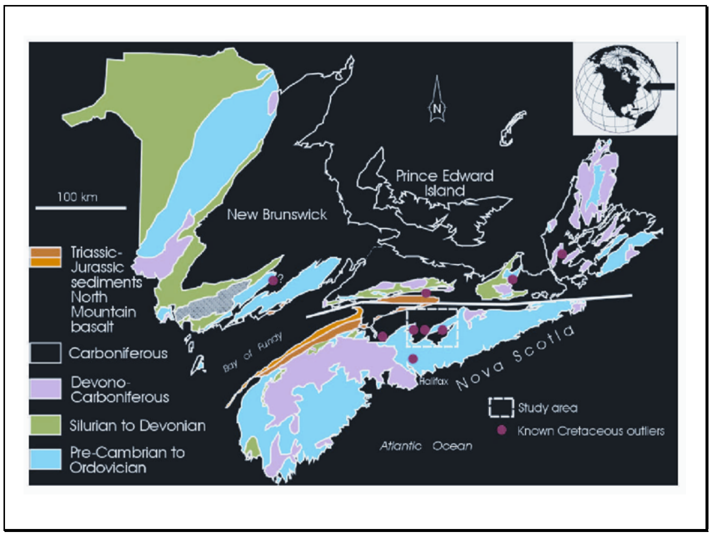

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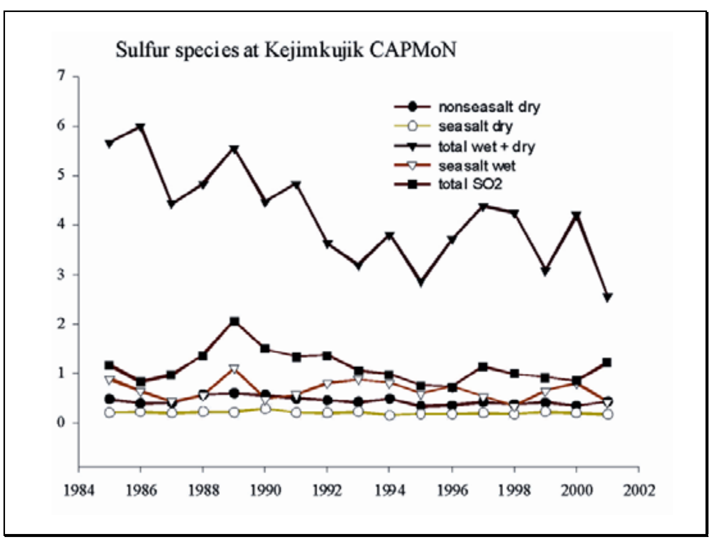

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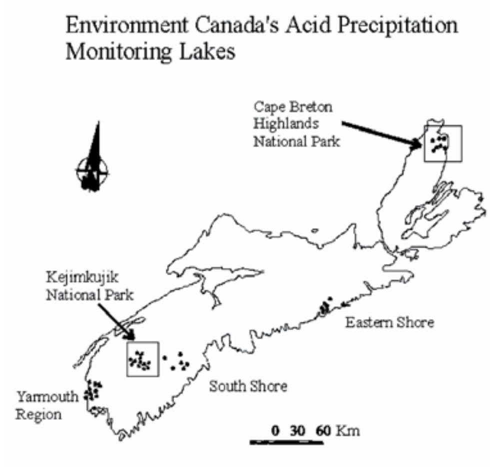


Slide 8

Chemistry changes in NS lakes from 1990 to 2002

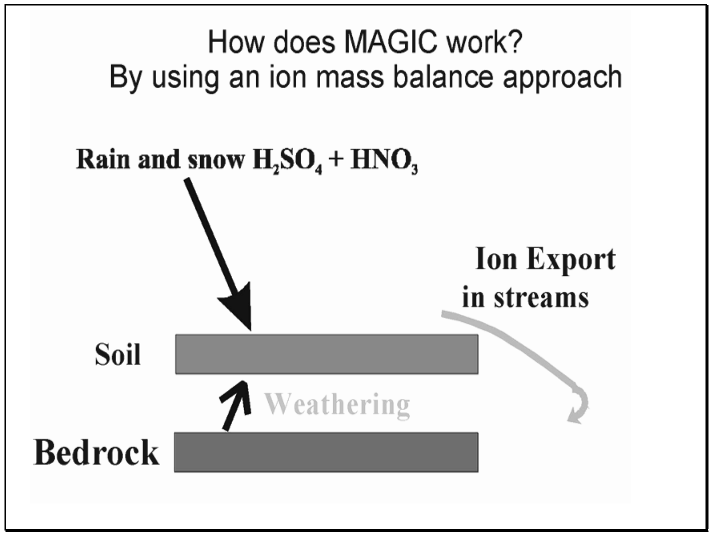
Sulfate	Up	Down	No change
Sulfate	0	32	37
pH	4	4	61
Gran ANC	1	23	45
Base cations	0	3	66

Slide 9

How can we predict how water chemistry will change in the future?

- The interactions between acid deposition and soils are quite complex
- In order to deal with this, we teamed up with Dr. Jack Cosby of the University of Virginia who developed an acidification model called: Model of Acidification of Groundwater In Catchments (MAGIC)

Slide 10



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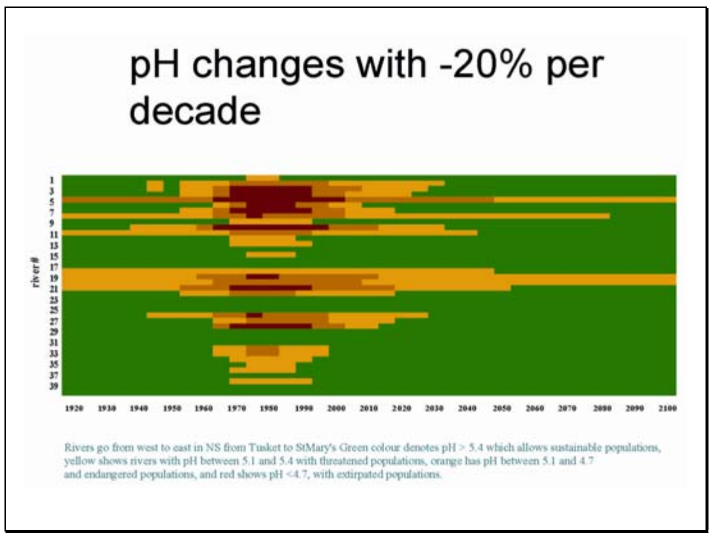
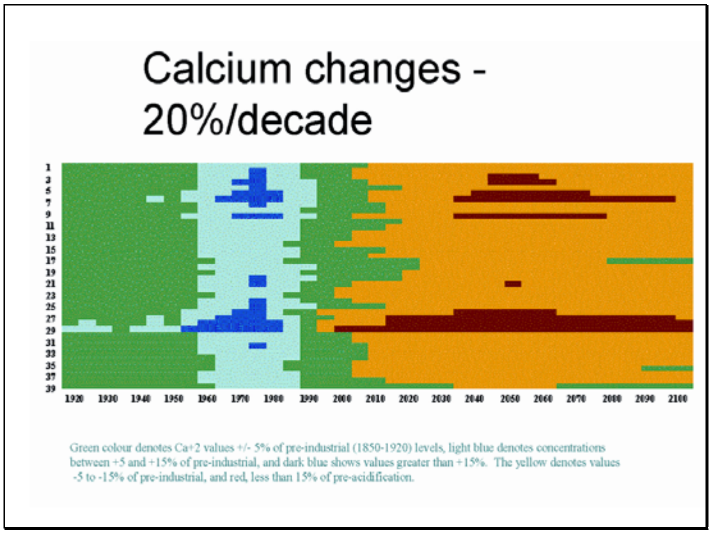


Slide 12

Is pH all there is?

- pH will react quite quickly to changes in deposition and improve some conditions important for biota. However, pH is difficult to measure and organic acids from wetlands complicate the picture.
- Other ions are involved in the buffering of acidification effect. How will they change?

Slide 13



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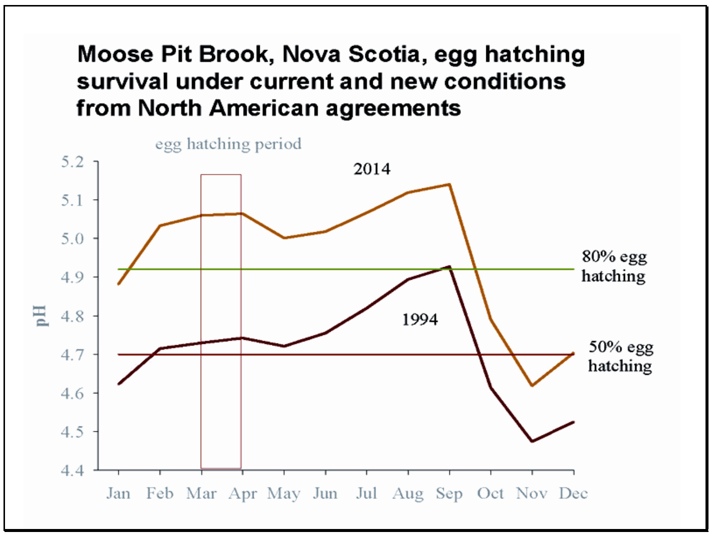

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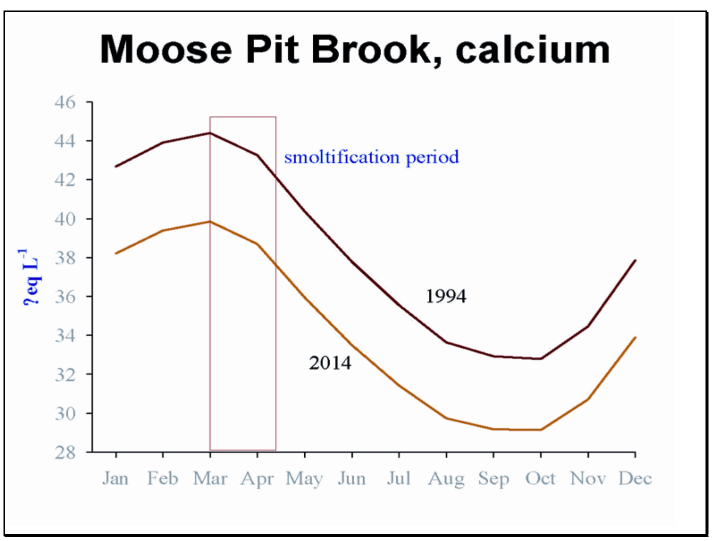


Slide 16

- So, there is a major improvement in the control of acid rain, but ecological recovery will take much longer to occur than we suspected. It thus makes a great deal of sense to attempt to aid the recovery of liming ecosystems.

Summary of Approaches to Mitigation in Published North American Work – Tom Clair

See also Appendix 6 – Clair and Hindar, unpublished. Liming aquatic ecosystems for acid rain mitigation : recent results and recommendations for the future

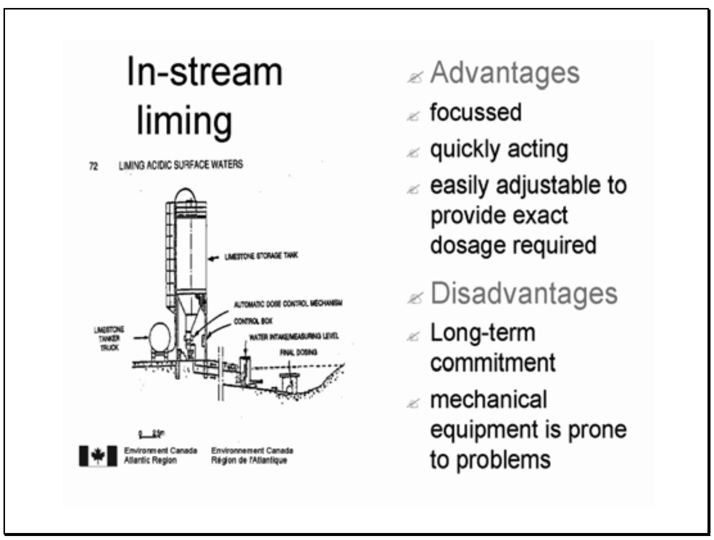
Slide 1

Liming Approaches

Tom Clair
Environment Canada

- Water liming
  - In-stream
  - Lake
  - Sediment gravel
- Catchment liming
  - Whole catchment
  - Recharge zone only

Slide 2



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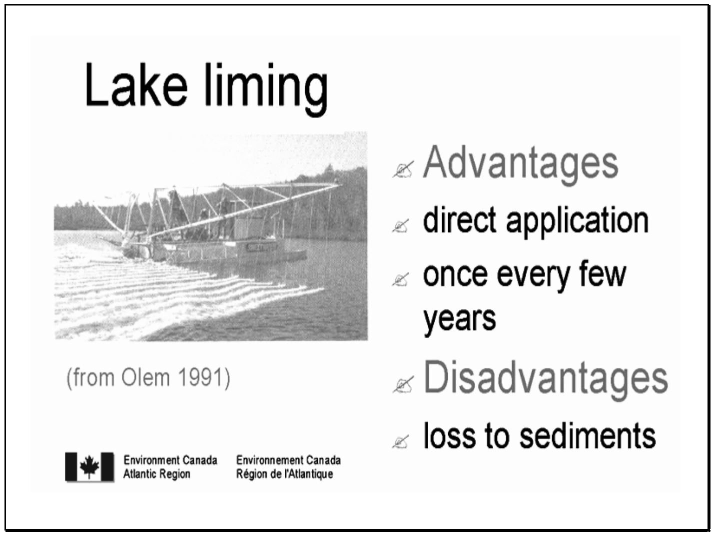

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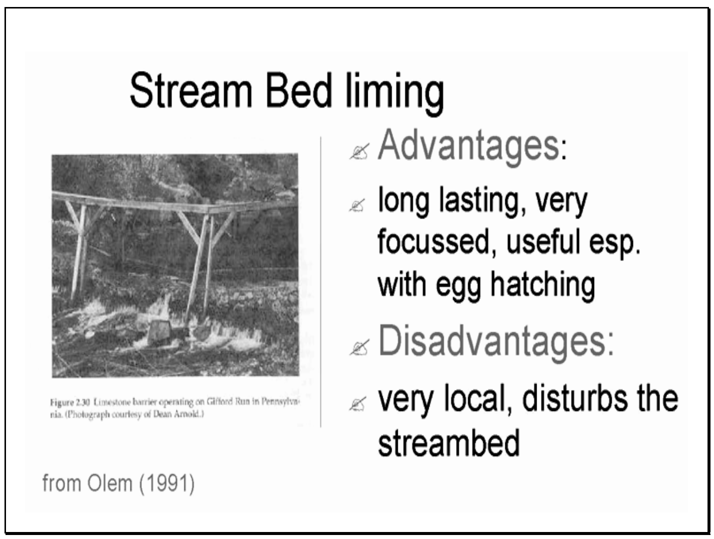

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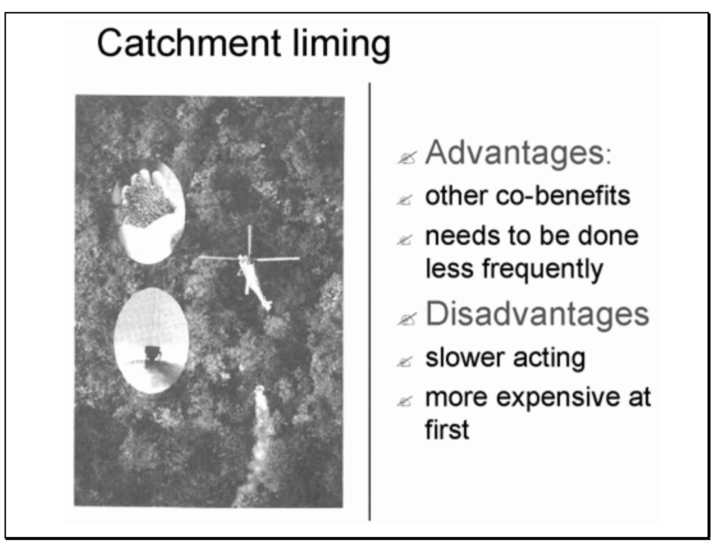


Slide 6

Different approaches used

Watershed Area = 2.819 km2
River 100m buffer Area= 0.667 km2

Slide 7

Buffering minerals
(from Olem 1991)

MITIGATION STRATEGIES 37

Table 2.3 Theoretical Neutralization Equivalents of Selected Materials

Common Name	Formula	Formula Weight	Theoretical Neutralization Equivalent (%)[a]
Limestone	$CaCO_3$	100.09	100
Dolomite	$CaCO_3$-$MgCO_3$	184.42	109
Sodium carbonate	Na_2CO_3	106.00	94
Sodium bicarbonate	$NaHCO_3$	84.00	119
Calcined lime	CaO	56.08	179
Calcined dolomite	CaO-MgO	96.40	207
Hydrated lime	$Ca(OH)_2$	74.10	135
Dolomitic hydrate	$Ca(OH)_2$-MgO	114.42	175
Pressure dolomitic hydrate	$Ca(OH)_2$-$Mg(OH)_2$	132.44	151
Caustic soda	NaOH	40.01	125

[a] Relative neutralization equivalent if pure $CaCO_3$ is assigned a value of 100%.

Slide 8

Liming approaches in North America

- From discussing with scientists and reading the literature, it is clear that there is no jurisdiction in North America that has an official policy on liming, nor has a set of guidelines for assisting in determining what methods to use and when to use them.

Slide 9

Liming in North America – Part 2

- All studies reported in the literature have been experimental or have been conducted by local groups with local concerns
- There is no central group in either Canada or the US which provides expertise or support based on experiences from elsewhere

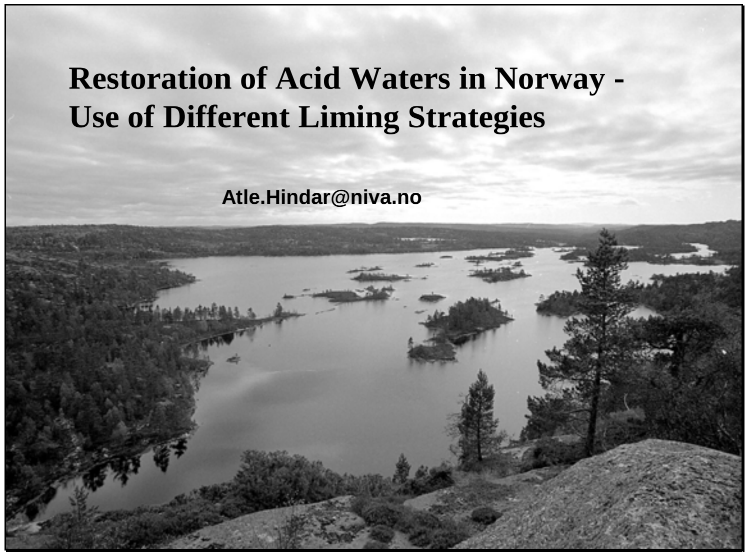
Slide 10

Liming in North America – Part 3

- Is there a need for such a group?
- Is there a way to involve governments in providing policy direction?
- We now see the light at the end of the acidification tunnel. How can we insure that we can accelerate the recovery of important ecosystems in a coherent, consistent fashion?

The Scandinavian Experience – Atlee Hindar

Slide 1



Slide 2

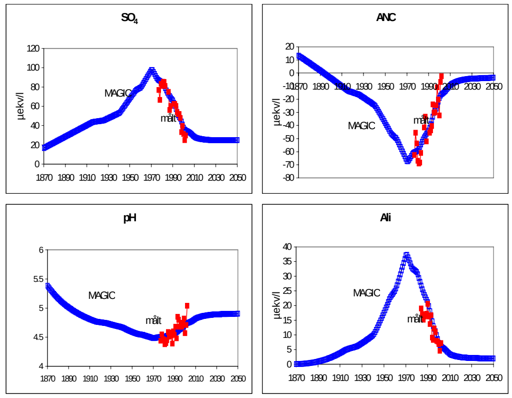
Content

- Acidification history
- Scenarios
- Mitigation strategies
- Success and obstacles
- Current status

NIVA

Slide 3

The MAGIC acidification history og Lake L. Hovvatn



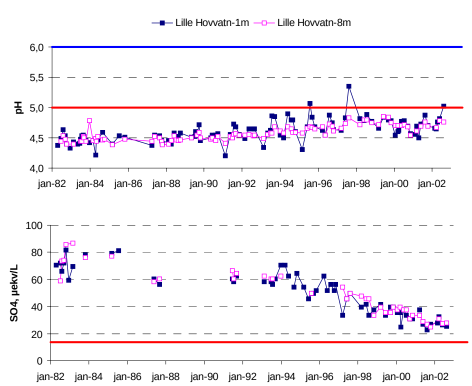
Slide 4

Loss of biology in Norway

- Almost 10 000 fish populations lost by 1990, another 5000 damaged
- Atlantic salmon vitually extinct in 25 major rivers
- Regional loss of biodiversity
- An area of 36 000 km^2 damaged
- About 90 % of area damaged in most affected areas

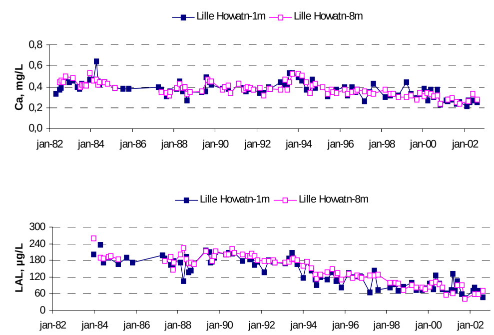
Slide 5

Recent changes in Lake Lille Hovvatn



Slide 6

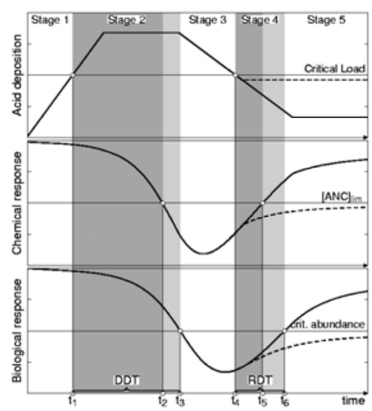
Less toxic?



NIVA

Slide 7

”Dynamic” change through time



DDT=damage delay time

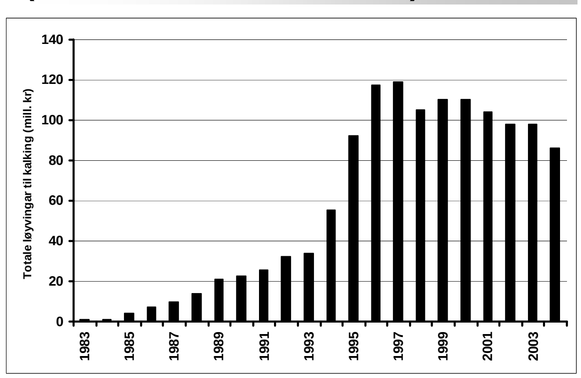
RDT=recovery delay time

Jenkins et al. 2003

NIVA

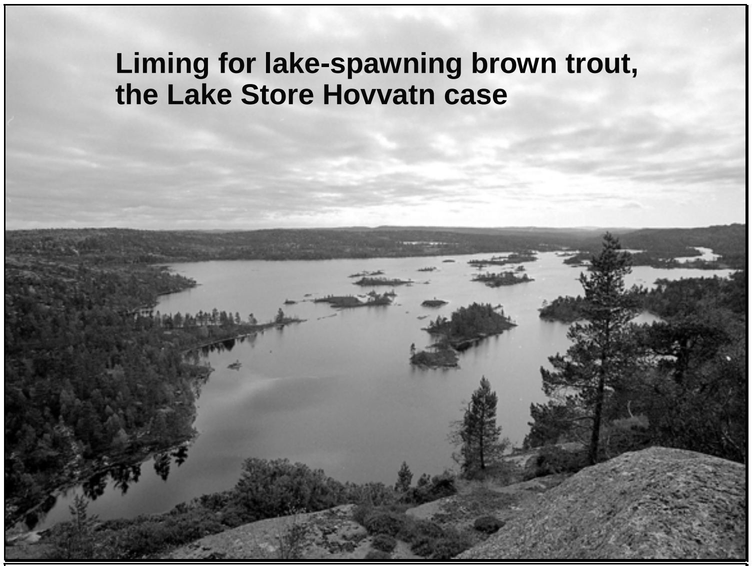
Slide 8

National funding of the liming program (total activities; NOK/7=USD)

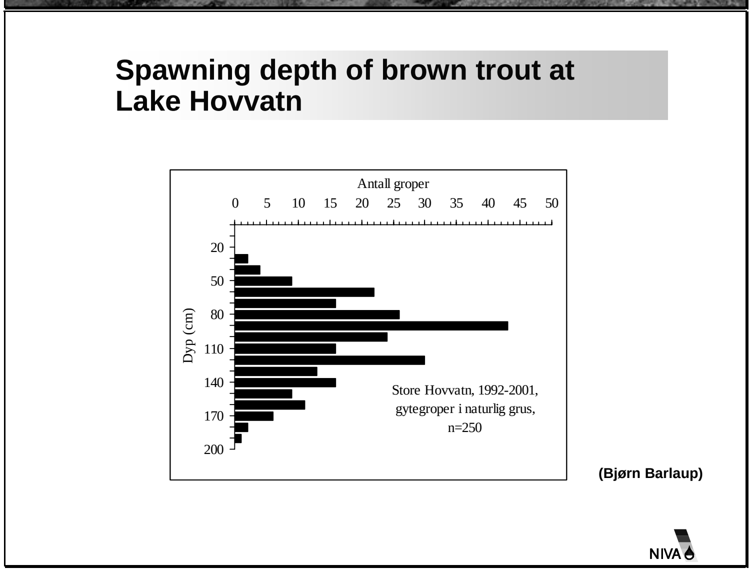


NIVA

Slide 9



Slide 10



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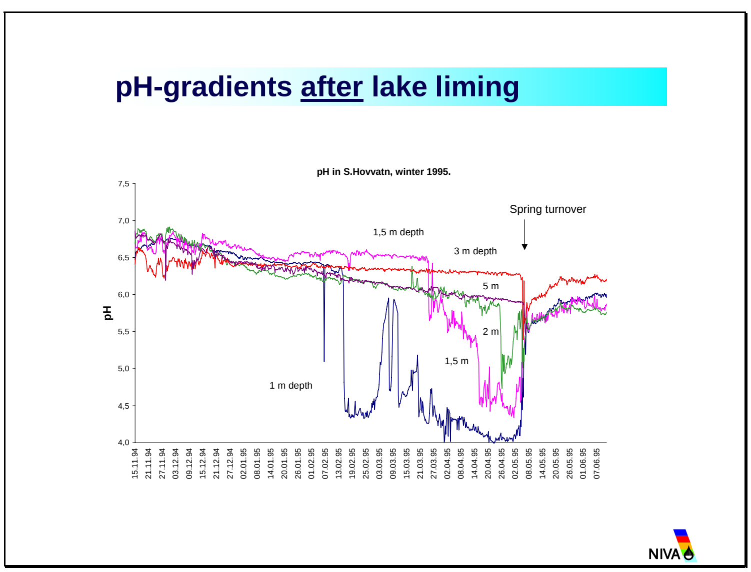
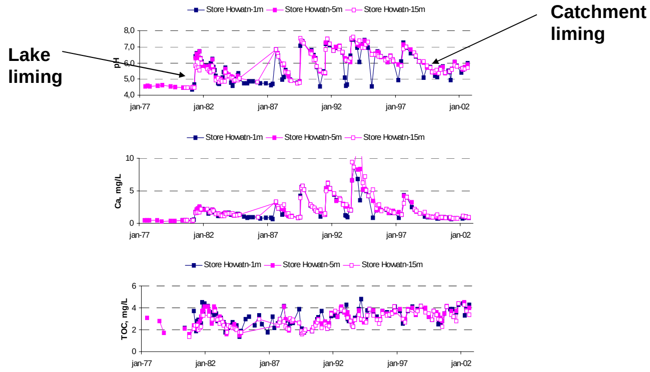


Slide 12

Liming of Lake S. Hovvatn



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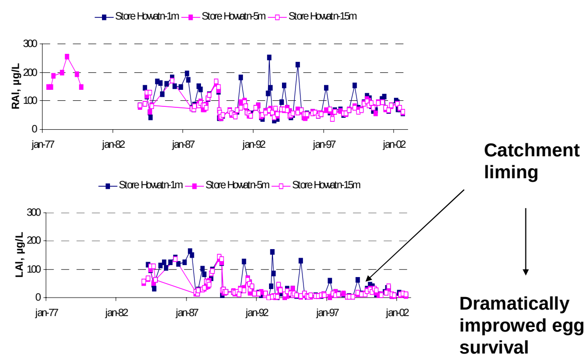
Slide 13

Change in aluminum



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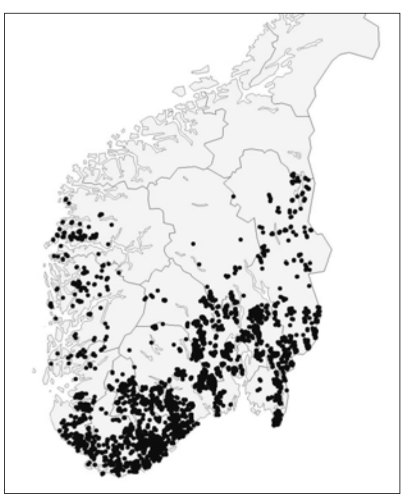

3000 limed lakes by 2004

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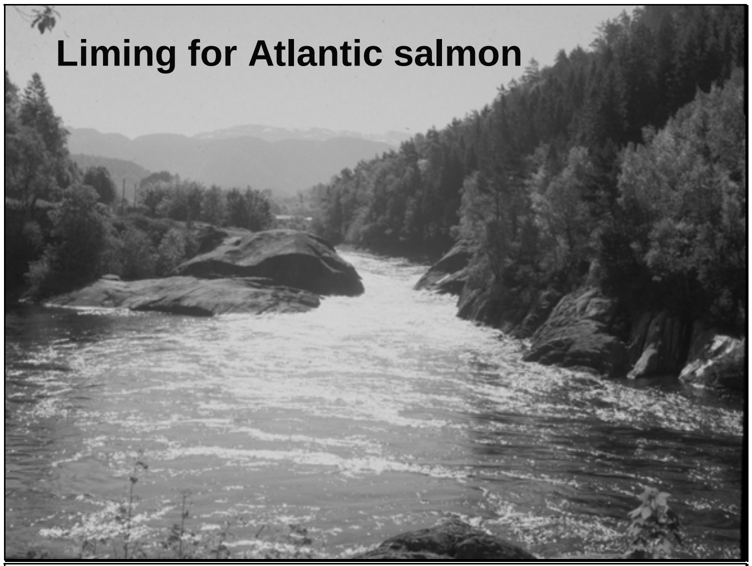
Slide 15



Slide 16

Atlantic salmon; current situation

- Extinct in 25 major rivers due to acidification
- The extreme sensitivity of smolts
- Rivers with high and rapidly changing runoff
- Episodic pulses of toxic water (sea-salt effects)

- 21 major rivers are limed for salmon by 2004

- Liming by lime dosers or in catchments?

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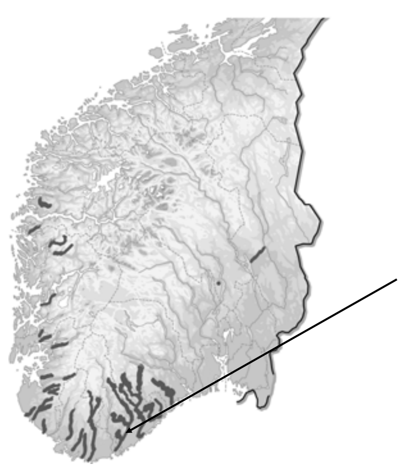
Slide 17

Liming of salmon rivers in South Norway



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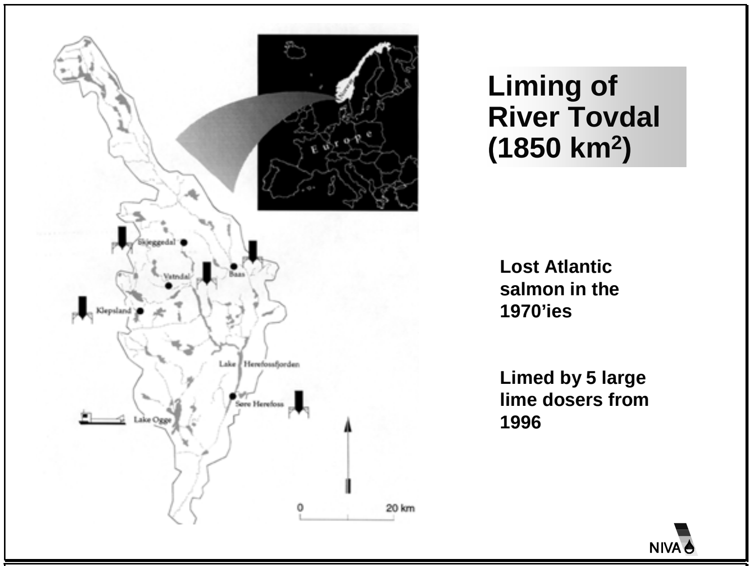
Slide 18



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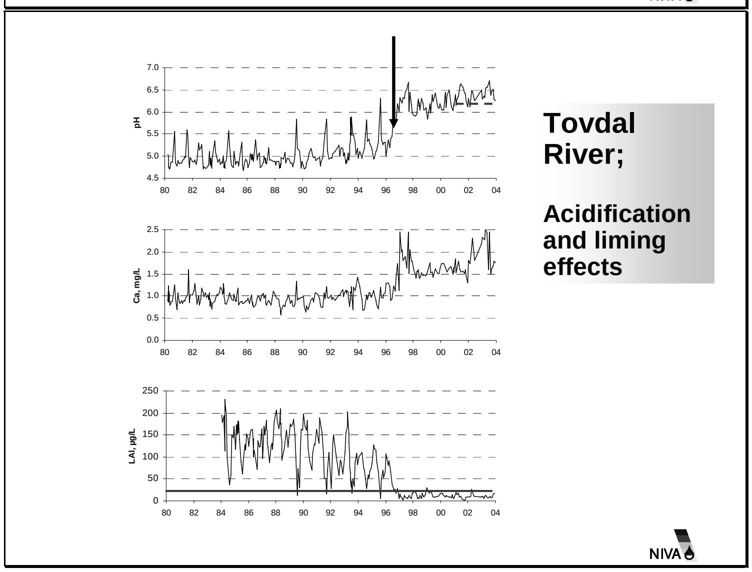

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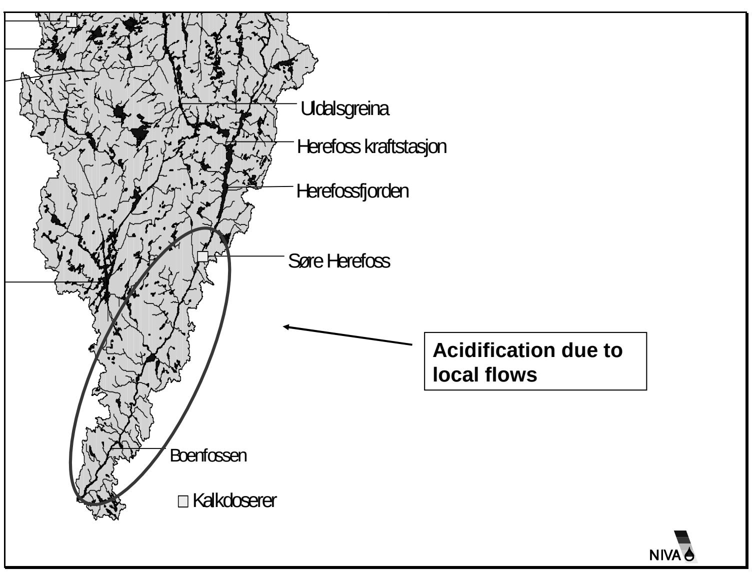

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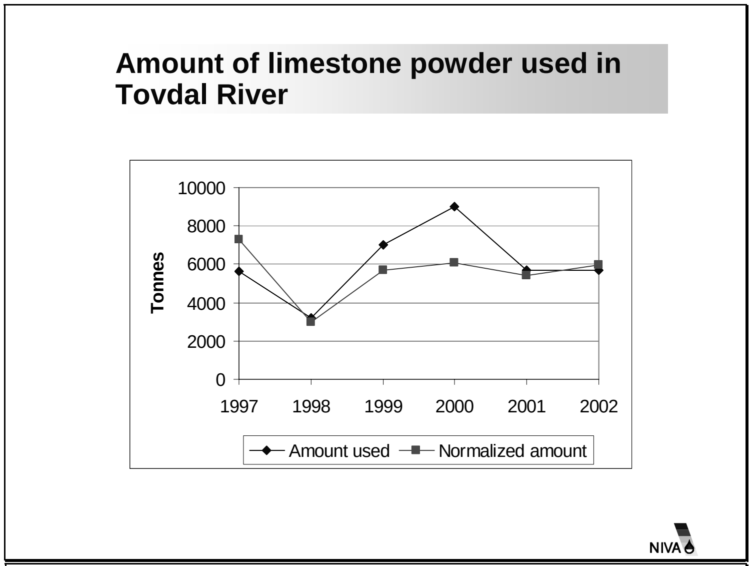

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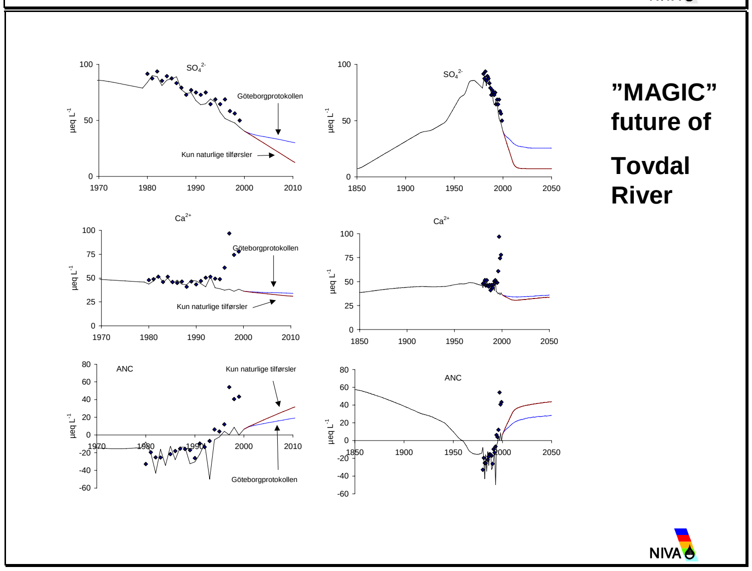

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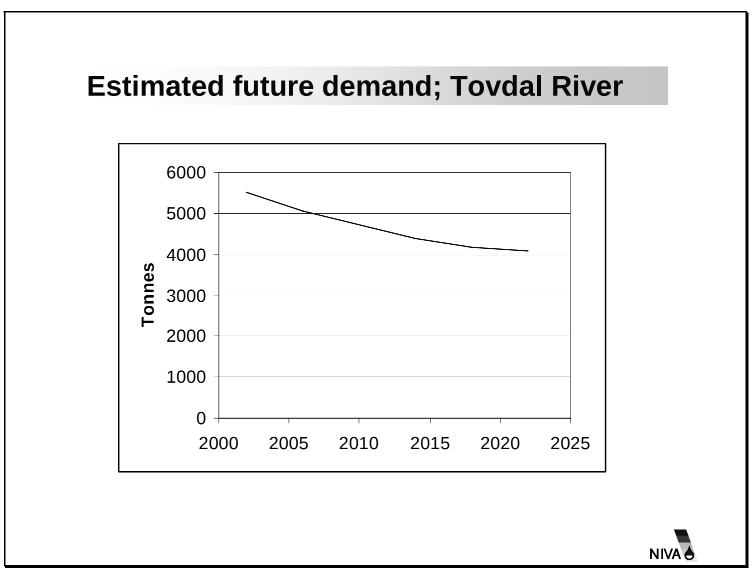

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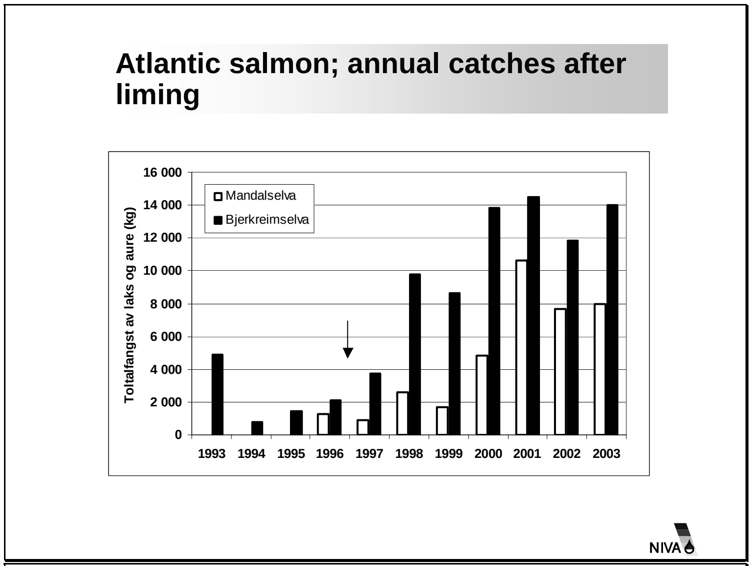

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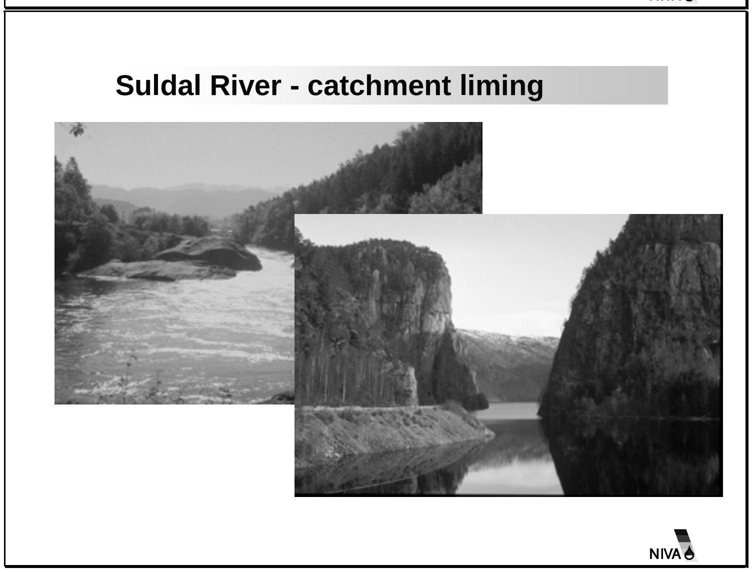

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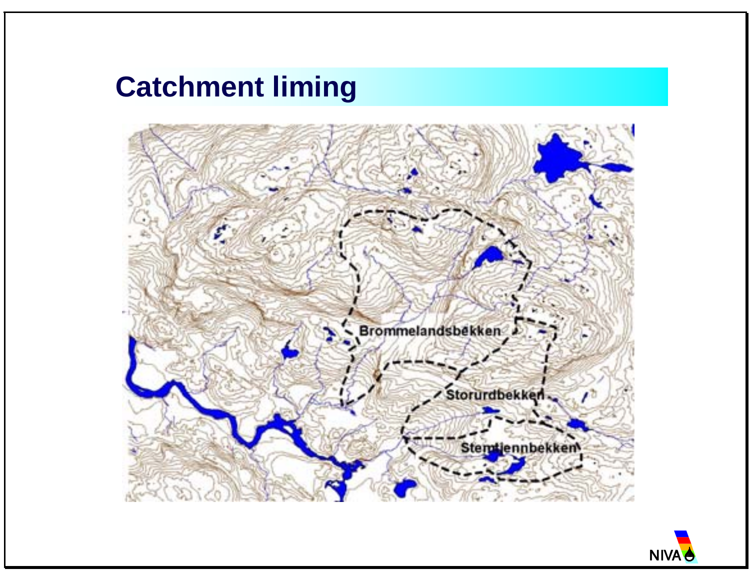
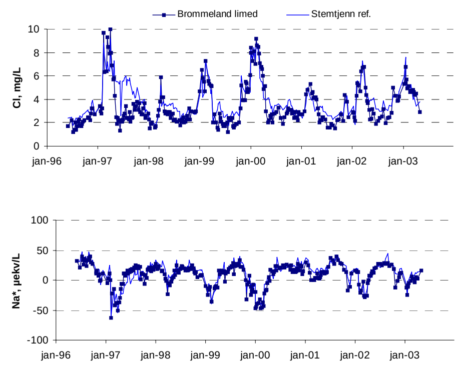


Slide 27

Episodic, sea-salt forced Al-mobilization



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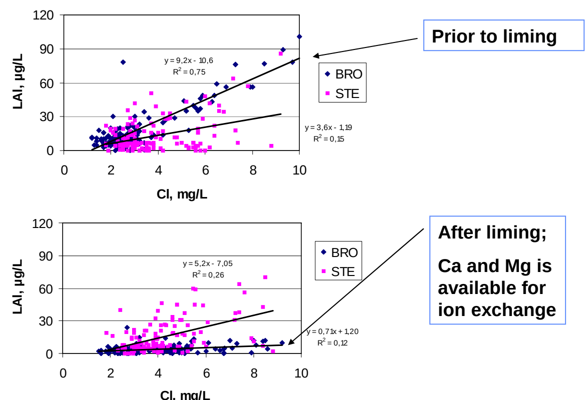
Catchment liming to mitigate sea-salt effects



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Concluding remarks

- Acidification history probably more dramatic than in North America
- Parallell research on causes, effects, consequences for biodiversity
- ANC as critical variabel as part of a Critical Load approach
- Atlantic salmon problems at low conc. of Al_i
- Liming almost exclusively a Scandinavian issue
- Different liming strategies developed; lake liming, dosers, catchment liming
- Recovery ”rapid” after liming

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Current status

- Emissions;
  - Large reductions in Europe; all done by 2010
  - Scenarios point out South-western Norway as acidified land forever
- Recovery;
  - Water chemistry is changing; chemical time delays
  - Water quality eventually improves; biological time delays
- Liming
  - 3000 lakes
  - 21 salmon rivers
- Increased biodiversity and salmon catches
- Dependent on a political willingnes to pay

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Approaches to Prioritizing Acid-impacted Salmon Populations for Recovery Initiatives

a) Southern Uplands – Peter Amiro

Slide 1

Program Prioritization

One approach

One approach to resolving the dilemma of the dependence on enhancement and its physical demand on hatchery resources versus the under capacity of those same facilities to fulfill the requirements for sustainability of the salmon population for the future.

A triage approach based on evaluating biological value and potential for recovery.

Slide 2

What to do?

- Determine genetic structure and population status of Southern Upland salmon.
- Seek classification under COSEWIC for listing as a Species at Risk.
- Convert enhancement actions to recovery actions.
- Continue habitat recovery actions.

Slide 3

Proposed recovery priorities

- Protect genetically unique stocks
- Work on remaining quality habitat first.
- Use status information to detect remnant populations and those at risk of extirpation.

Slide 4

Table 10. Recovery srategey prioritzation for Atlantic salmon in Southern Upland rivers of Nova Scotia based on population origin, population size, and mean annual pH.

Stock genetics	Priority	Adult population	Mean annual pH	Recovery strategy priorities: First	Second	Third
Distinct	9	>100	>5.1	Habitat recovery	Supplementation level 1	
	7		<5.1>4.7	Habitat recovery	pH treatment to attain 2,000 wild smolts	
	8	(unlikely)	<4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 3	
	6	<100>50	>5.1	Habitat recovery	Supplementation level 2	
	2		<5.1>4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 2	
	5		<4.7	Supplementation level 2	pH treatment to attain viable smolt migrants	Supplementation level 3
	4	<50	>5.1	Habitat recovery	Supplementation level 3	Supplementation level 4
	1					
	3					
Transplanted	18	>10				
	16		<5.1>4.7	Habitat recovery	pH treatment to attain 2,000 wild smolts	Supplementation level 2
	17		<4.7	pH treatment to attain smolt migration path	Supplementation level 0	
	15	<100>50	>5.1	Habitat recovery	Supplementation level 1	
	11		<5.1>4.7	Habitat recovery	pH treatment to attain 2,000 wild smolts	Supplementation level 2
	14		<4.7	pH treatment to attain smolt migration path	Supplementation level 0	
	13	<50	>5.1	Habitat recovery	Supplementation level 2	
	10		<5.1>4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 2	
	12		<4.7	pH treatment to attain smolt migration path	Supplementation level 0	

A Proposed Recovery Strategy

See Table 1

Slide 5

Intervention levels

- **0. Transplantation from another source.**
- **1. 30-50 wild adult broodstock collected annually, five year program.**
- **2. 30-50 wild and hatchery adult broodstock collected annually, five year program.**
- **3. 30-50 wild broodstock, mixture of adult and juvenile males or juvenile females grown to maturity, five year program.**
- **4. 100-300 wild broodstock from wild juvenile collections, Recovery Program indefinite. (Live Gene Bank)**

Slide 6

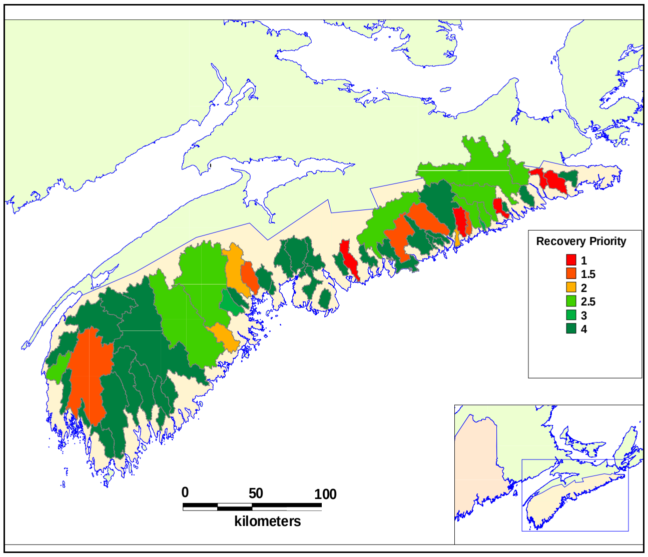
Table 9. Possible recovery prioitization based on stock uniqueness, pH , and residual population status for the rivers of the Southern Upland of Nova Scotia.

River number	River name	Salmon rearing area 00 m² unit	pH category	Stocking history	Recreational catch, 1996 Small	Large	Presence of salmon since 1986	Prognosis at 10% marine survival	Prognosis at 5% marine survival	Den./100m² all parr year 2000	Stock weight	pH weight	Den. rel. to 3rd pst.val 4.0	Recovery score	Recovery priority
1	Nictaux		2	Native						0.4	1	1	1	3	1
2	Round Hill		3	None						1.8	1	1	1	3	1
36	Salmon (L. Echo)	7,493	2	None			Present	Extirpated	Extirpated	0.0	1	1	1	3	1
50	Salmon (P.D.)	7,954	3	None			Present	At risk	Extirpated	0.8	1	1	1	3	1
56	Gaspereau Bk	2,826	3	None			Absent	At risk	Extirpated	2.1	1	1	1	3	1
62	Issacs Harbour	2,469	2	None	0	0	Absent	Extirpated	Extirpated	0.5	1	1	1	3	1
63	New Harbour	3,148	3	None	1	0	Absent	Extirpated	Extirpated	0.1	1	1	1	3	1
17	Sable	9,198	1	None				Extirpated	Extirpated	0.0	1	0	0	0	4
18	Tidney		1	None						0.0	1	0	0	0	4
19	Mersey		2	Local	5	0				0.0	0.5	1	0	0	4
24	Martins	8,334	2	Local				Extirpated	Extirpated	0.0	0.5	1	0	0	4
28	Little East		2	None							1	1	0	0	4
29	Ingram	5,701	2	Local	7	0	Present	Extirpated	Extirpated	0.9	0.5	1	1	2.5	1.5
30	Indian		2	None						0.0	1	1	0	0	4
31	East		2	None						0.0	1	1	0	0	4
32	Nine Mile	5,569	1	None				Extirpated	Extirpated	0.0	1	0	0	0	4
33	Pennent		1	None							1	0	0	0	4
34	Sackville	6,772	3	Local	140	14	Present	Extirpated	Extirpated		0.5	1	0	0	4
35	Salmon (L Major)	750	2	None				Extirpated	Extirpated	0.0	1	1	0	0	4
37	West Bk Porters	1,185		None				Extirpated	Extirpated	0.0	1	FALSE	0	0	4
38	East Bk Porters	2,394		None				Extirpated	Extirpated	0.0	1	FALSE	0	0	4
39	Chezzetcook	1,757	3	None				At risk	Extirpated	0.0	1	1	0	0	4
41	Salmon (Hfx)	2,834	2	None				At risk	Extirpated	0.0	1	1	0	0	4
43	Tangier	22,717	2	Local			Absent	Extirpated	Extirpated	0.0	0.5	1	0	0	4
44	E Taylor Bay	260	3	None				Extirpated	Extirpated	0.0	1	1	0	0	4
45	W Taylor Bay	1,300	3	None			Absent	Extirpated	Extirpated	0.0	1	1	0	0	4
46	Little West	4,087		None						0.0	1	FALSE	0	0	4
48	East (Sh Hbr)	30,501	2	Local	34	0	Present	At risk	Extirpated	0.0	0.5	1	0	0	4
57	Gegogan	382	4	None			Absent	At risk	Extirpated	0.0	1	0.5	0	0	4
60	Indian	9,743	1	None	4	4		Extirpated	Extirpated		1	0	0	0	4

Application of a Recovery Priority Strategy

See Table 2

Slide 7



Spatial distribution of recovery priorities from highest RED to lowest DARK GREEN.

Slide 8

Actions since 2001

- Gold River parr collected, grown to adults and released to Gold River in 2003.
- Parr (Age 0 to 2) collected in 2003 from New Harbour (8), Isaacs Harbour (1), Indian Harbour (18), Gaspereau Brook (8), Ecum Secum (30), Salmon River Port Dufferin (34), Kirby River (2).

Table 1. Recovery strategy prioritization for Atlantic salmon in Southern Upland rivers of Nova Scotia based on population origin, population size, and mean annual pH.

Stock genetics	Priority	Adult population	Mean annual pH	Recovery strategy priorities: First	Second	Third
Distinct	9	>100	>5.1	Habitat recovery	Supplementation level 1	
	7		<5.1>4.7	Habitat recovery	pH treatment to attain 2,000 wild smolts	
	8	(unlikely)	<4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 3	
	6	<100>50	>5.1	Habitat recovery	Supplementation level 2	
	2		<5.1>4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 2	
	5		<4.7	Supplementation level 2	pH treatment to attain viable smolt migrants	Supplementation level 3
	4	<50	>5.1	Habitat recovery	Supplementation level 3	Supplementation level 4
	1		<5.1>4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 3	Supplementation level 4
	3		<4.7	pH treatment to attain smolt migration path	Supplementation level 3	Supplementation level 4
Transplanted	18	>100	>5.1	Habitat recovery	Supplementation level 1	
	16		<5.1>4.7	Habitat recovery	pH treatment to attain 2,000 wild smolts	Supplementation level 2
	17		<4.7	pH treatment to attain smolt migration path	Supplementation level 0	
	15	<100>50	>5.1	Habitat recovery	Supplementation level 1	
	11		<5.1>4.7	Habitat recovery	pH treatment to attain 2,000 wild smolts	Supplementation level 2
	14		<4.7	pH treatment to attain smolt migration path	Supplementation level 0	
	13	<50	>5.1	Habitat recovery	Supplementation level 2	
	10		<5.1>4.7	pH treatment to attain 2,000 wild smolts	Supplementation level 2	
	12		<4.7	pH treatment to attain smolt migration path	Supplementation level 0	

Supplementation level:

- **0** Tranplantation from another source.
- **1** 30-50 wild adult broodstock collected annually, 5 year program.
- **2** 30-50 wild and hatchery adult broodstock collected annually, 5 year program.
- **3** 30-50 wild broodstock, mixture of adult and juvenile males or juvenile females grown to maturity, 5 year program.
- **4** 100-300 wild broodstock from wild juvenile collections, Recovery Program indefinite. (Live Gene Bank)

Table 2. Possible recovery prioritization based on stock uniqueness, pH, and residual population status for the rivers of the Southern Upland of Nova Scotia.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			Salmon			Recreational		Presence	Prognosis		Den./100m^2			Den. rel. to	
2	River		rearing area	pH	Stocking	catch, 1996		of salmon	at 10%	at 5%	all parr	Stock	pH	3rd pst.val	Recovery
3	number	River name	100 m^2 units	category	history	Small	Large	since 1986	marine survival	marine survival	year 2000	weight	weight	4.2	score
4															
5	1	Nictaux		2	Native						0.4	1	1	1	3
6	2	Round Hill		3	None						1.8	1	1	1	3
7	36	Salmon (L. Echo)	7,493	2	None			Present	Extirpated	Extirpated	0.0	1	1	1	3
8	50	Salmon (P.D.)	7,954	3	None			Present	At risk	Extirpated	0.8	1	1	1	3
9	56	Gaspereau Bk	2,826	3	None			Absent	At risk	Extirpated	2.1	1	1	1	3
10	62	Issacs Harbour	2,469	2	None	0	0	Absent	Extirpated	Extirpated	0.5	1	1	1	3
11	63	New Harbour	3,148	3	None	1	0	Absent	Extirpated	Extirpated	0.1	1	1	1	3
12	10	Tusket	150,780	2	Local	133	55	Present	Extirpated	Extirpated	2.0	0.5	1	1	2.5
13	26	Middle	12,290	2	Local	14	0	Present	Extirpated	Extirpated	2.8	0.5	1	1	2.5
14	29	Ingram	5,701	2	Local	7	0	Present	Extirpated	Extirpated	0.9	0.5	1	1	2.5
15	42	Ship Harbour	20,518	4	None	1	0		At risk	At risk	3.4	1	0.5	1	2.5
16	47	West (Sh Hbr)	20,079	2	Local	20	1	Present	Extirpated	Extirpated	3.5	0.5	1	1	2.5
17	51	Quoddy	6,849	4	None				At risk	Extirpated	0.8	1	0.5	1	2.5
18	59	Indian Harbour Lakes		4	None						0.3	1	0.5	1	2.5
19	21	Petite	7,174	4	Local	126	16	Present	At risk	Extirpated	4.0	0.5	0.5	1	2
20	25	Gold	21,962	3	Native	188	71	Present	At risk	Extirpated	26.8	1	1	0	2
21	27	East (Chester)	4,598	2	None	1	2	Absent	Extirpated	Extirpated	4.8	1	1	0	2
22	49	Kirby	1,604	3	None				At risk	Extirpated	27.0	1	1	0	2
23	8	Salmon (Digby)	9,797	3	Local	94	44	Present	At risk	Extirpated	7.6	0.5	1	0	1.5
24	20	Medway	99,174	3	Local	490	88	Present	At risk	Extirpated	6.6	0.5	1	0	1.5
25	22	LaHave	75,046	3	Local	1,514	327	Present	At risk	At risk	13.0	0.5	1	0	1.5
26	40	Musquodoboit	23,125	4	Native	209	116	Present	Sustained	At risk	47.4	1	0.5	0	1.5
27	52	Moser	15,270	3	Local	35	0	Absent	At risk	Extirpated	9.2	0.5	1	0	1.5
28	54	Ecum Secum	9,894	4	None	27	5	Present	At risk	Extirpated	10.8	1	0.5	0	1.5
29	55	Liscomb	34,960	2	Local	1	0	Absent	Extirpated	Extirpated	9.1	0.5	1	0	1.5
30	58	St Marys	58,717	4	Native	596	177	Present	Sustained	At risk	15.5	1	0.5	0	1.5
31	61	Country Harbour	3,457	4	None	4	5	Present	Sustained	At risk	19.7	1	0.5	0	1.5
32	23	Mushamush	2,743	4	Local	20	2		Sustained	At risk	29.2	0.5	0.5	0	1
33	53	Smith	1,055		None				At risk	At risk	9.4	1	FALSE	0	1
34	3	Bear		2	Local						0.0	0.5	1	0	0
35	4	Sissibo		2	None						0.0	1	1	0	0
36	5	Beliveau		4	None						0.0	1	0.5	0	0
37	6	Boudreau		4	None							1	0.5	0	0
38	7	Meteghan		4	Local	12	5				0.0	0.5	0.5	0	0
39	9	Annis		3	None						0.0	1	1	0	0
40	11	Argyle		1	None						0.0	1	0	0	0
41	12	Barrington	8,877	1	None			Absent	Extirpated	Extirpated		1	0	0	0
42	13	Clyde	55,348	1	Local	46	14		Extirpated	Extirpated	0.0	0.5	0	0	0
43	14	Roseway	33,012	1	None			Absent	Extirpated	Extirpated	0.0	1	0	0	0
44	15	Jordan	29,206	1	Local	0	0	Absent	Extirpated	Extirpated	0.0	0.5	0	0	0
45	16	East		1	None						0.0	1	0	0	0
46	17	Sable	9,198	1	None				Extirpated	Extirpated	0.0	1	0	0	0
47	18	Tidney		1	None						0.0	1	0	0	0
48	19	Mersey		2	Local	5	0				0.0	0.5	1	0	0
49	24	Martins	8,334	2	Local				Extirpated	Extirpated	0.0	0.5	1	0	0
50	28	Little East		2	None							1	1	0	0
51	30	Indian		2	None						0.0	1	1	0	0
52	31	East		2	None						0.0	1	1	0	0
53	32	Nine Mile	5,569	1	None				Extirpated	Extirpated	0.0	1	0	0	0
54	33	Pennent		1	None							1	0	0	0
55	34	Sackville	6,772	3	Local	140	14	Present	Extirpated	Extirpated		0.5	1	0	0
56	35	Salmon (L Major)	750	2	None				Extirpated	Extirpated	0.0	1	1	0	0
57	37	West Bk Porters	1,185		None				Extirpated	Extirpated	0.0	1	FALSE	0	0
58	38	East Bk Porters	2,394		None				Extirpated	Extirpated	0.0	1	FALSE	0	0
59	39	Chezzetcook		3	None				At risk	Extirpated	0.0	1	1	0	0
60	41	Salmon (Hfx)	2,834	2	None				At risk	Extirpated	0.0	1	1	0	0
61	43	Tangier	22,717	2	Local			Absent	Extirpated	Extirpated	0.0	0.5	1	0	0
62	44	E Taylor Bay	260	3	None				Extirpated	Extirpated	0.0	1	1	0	0
63	45	W Taylor Bay	1,300	3	None			Absent	Extirpated	Extirpated	0.0	1	1	0	0
64	46	Little West	4,087		None						0.0	1	FALSE	0	0
65	48	East (Sh Hbr)	30,501	2	Local	34	0	Present	At risk	Extirpated	0.0	0.5	1	0	0
66	57	Gegogan	382	4	None			Absent	At risk	Extirpated	0.0	1	0.5	0	0
67	60	Indian	9,743	1	None	4	4		Extirpated	Extirpated		1	0	0	0
68	64	Larrys	2,632	1	None			Absent	Extirpated	Extirpated		1	0	0	0
69	65	Cole Harbour	2,730	2	None	0	0		Extirpated	Extirpated		1	1	0	0

Weights and sums formulae:

=IF(L10=”NATIVE”,1,IF(L10=”LOCAL”,0.5,IF(L10=”NONE”,1)))
=IF(M10=1,0,IF(M10=2,1,IF(M10=3,1,IF(M10=4,0.5))))
=IF(N10=0,0,IF(N10>N$8,0,1))
=IF(O10<>0,SUM(L10:N10),0)

b) Maine – Dan Kircheis

For additional considerations, see slides 10-17 in Dennys River Pilot Liming Project.

River Selection Criteria Matrix	Sheepscot	Ducktrap	Cove	Narraguagus	Pleasant	Machias	East Machias	Dennys
Biological significance								
>500 Units Rearing habitat	1	1	0	1	1	1	1	1
Spawning habitat	1	1	1	1	1	1	1	1
Population assessment data								
basin-wide parr assessments	0	0	0	1	1	0	0	1
smolt trapping capability	1	0	0	1	1	0	0	1
adult trapping capability	0	0	0	1	1	0	0	1
electrofishing data time series	1	1	1	1	1	1	1	1
redd count data time series	1	1	1	1	1	1	1	1
emergent fry trapping	0	0	0	0	0	0	0	1
smolt physiology data	1	0	0	1	1	0	0	1
Behavioral studies								
pen-reared adult reproductive success study	0	0	0	0	0	0	0	1
smolt telemetry data	0	0	0	1	0	0	0	1
adult telemetry	0	0	0	1	0	0	1	1
fry drift study	0	0	0	0	0	0	0	1
Stocking								
Hatchery releases of fry	1	0	0	1	1	1	1	1
Hatchery releases of smolts	0	0	0	0	1	0	0	1
Ecological assessment data								
DEP biological monitoring station	1	0	0	1	1	0	1	1
water quality data	1	1	1	1	1	1	1	1
embeddedness	0	0	1	0	1	0	1	1
Geophysical Factors								
GIS habitat maps	1	1	1	1	1	1	1	1
IFIM data	0	0	0	1	1	1	0	1
Controlled flow	0	0	0	0	0	0	0	1
Totals	**10**	**6**	**6**	**15**	**15**	**8**	**10**	**21**

Evening Presentations

George Ferguson, Past President, Nova Scotia Salmon Association, Manager, Acid Rain Mitigation Project.

- Described the cooperation of the Atlantic Salmon Federation and NSSA in deciding to act by forming the Acid Rain Mitigation Committee of the NSSA in January 2001. Terms of reference for committee included soliciting the help of experts from Norway to guide their approach; developing a strategy to move action forward on the acid rain mitigation front, in other words, to begin mitigation in some capacity; to renew concern for the problem among the public and elected officials because the clean air act was not producing the results forecast.

- Indicated the committee had produced two products to date, a report from the consultant from Norway, Atle Hindar with NIVA which recommended a liming approach on several rivers; and a business plan that provided a summary of the project and costs related to installation and operation of a limestone doser on the West River, Sheet Harbour.

- Reiterated the concern that the message still wasn't getting out to the general public and there seemed little government desire to deal with the loss of fish species and the death of rivers in Nova Scotia.

- More detailed presentation on the West River liming project was to be presented the next day at the workshop by Shane O'Neil.

Lowell Demond, Past President, LaHave River Salmon Association

- Described the liming project on Big LaHave Lake on the LaHave River. Summarized the use of limestone on the winter lake ice and the cooperation among NGO's to get the job done.

- Expressed concern about the confusing messages received from Fisheries and Oceans specialists regarding the value of such a project. Indicated that Dr. Walton Watt had provided them advice and guidance in the early planning and implementation phases. More recently the direction they have received is that the liming project is unlikely to produce a valuable benefit to the conservation of wild LaHave River Atlantic salmon or to the return of salmon to the river.

- Also indicated that their liming group (on behalf of the LaHave River Association) had written to Fisheries and Oceans some time ago for a detailed explanation on the pros and cons of liming related to their project and for some clear direction for future action. Reminded audience that they were still waiting for a response.

- Dr. Marshall responded that they would get a letter in short order.

Mitigation : Summary Overviews of Recent/Current and Planned Projects

a) Dennys River, Maine – Dan Kircheis

Slide 1

Dennys River Pilot Liming Project

Project Update and Overview
2004

Slide 2

- Why
- Goals and objectives
- Drainage selection
- Site selection
- Product and mechanism for delivery
- Assessment plans
- Permitting process

Slide 3

Justification

- Smolt physiology
- Water chemistry data
- Maine TAC ad hoc committee
- 2003 water chemistry workshop
- The National Academy of Science
- International liming efforts for fisheries enhancement and restoration

Slide 4

NOAA – Fisheries Justification

- Critically low stock status
- "no action" is not an option
- Current recovery efforts have been mostly unsuccessful
- We need to, at least, explore or experiment with mechanisms to minimize or eliminate known threats

Slide 5

The liming project is an experiment that will accomplish the following:

– Identify or reject liming as a tool to add to the salmon recovery box

– Further identify the threat of water chemistry to our rivers

– We can, at least, say we tried it!!

Slide 6

Liming Project Goals

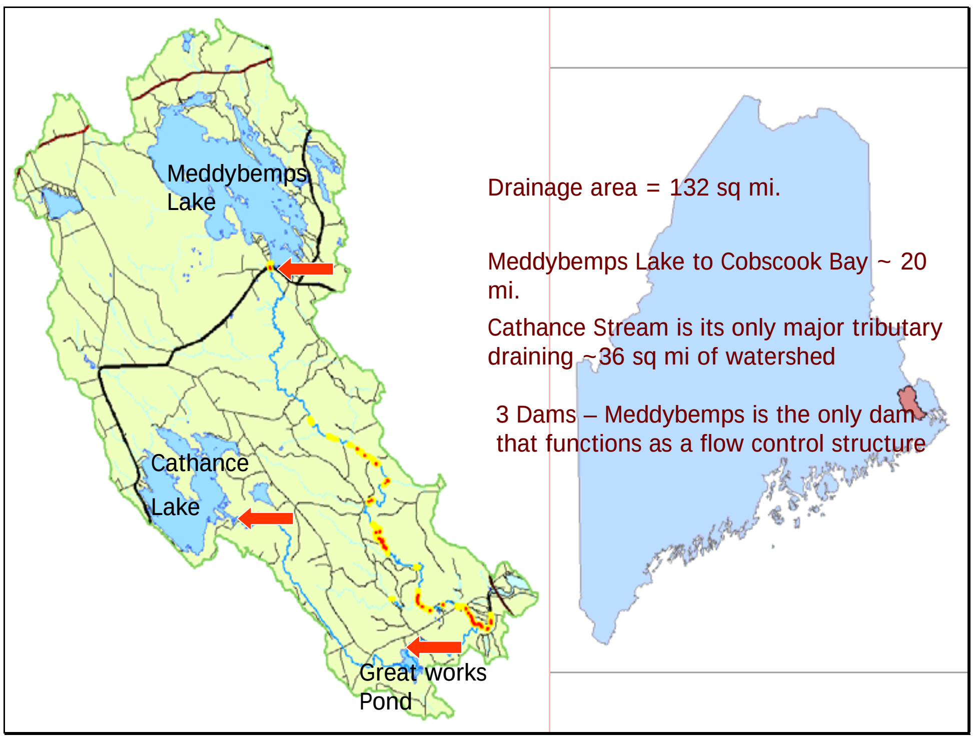
- THE MISSION: *"Implement a pilot liming project to evaluate its benefits to Atlantic salmon restoration in Eastern Maine"*

- THE VISION*: "Enhance water quality to benefit juvenile Atlantic salmon production and seawater tolerance and other community-specific species and monitor ecosystem indicators."*

Slide 7

The Dennys River

Slide 8



Slide 9

Why we selected the Dennys

Slide 10

Stocking and Assessment History

River Selection Criteria Matrix

	Sheepscot	Ducktrap	Cove	Narraguagus	Pleasant	Machias	East Machias	Dennys
Biological significance								
>500 Units Rearing habitat	1	1	0	1	1	1	1	1
Spawning habitat	1	1	1	1	1	1	1	1
Population assessment data								
basin-wide parr assessments	0	0	0	1	1	0	0	1
smolt trapping capability	1	0	0	1	1	0	0	1
adult trapping capability	0	0	0	1	1	0	0	1
electrofishing data time series	1	1	1	1	1	1	1	1
redd count data time series	1	1	1	1	1	1	1	1
emergent fry trapping	0	0	0	0	0	0	0	1
smolt physiology data	1	0	0	1	1	0	0	1
Behavioral studies								
pen-reared adult reproductive success study	0	0	0	0	0	0	0	1
smolt telemetry data	0	0	0	1	0	0	0	1
adult telemetry	0	0	0	1	0	0	1	1
fry drift study	0	0	0	0	0	0	0	1
Stocking								
Hatchery releases of fry	1	0	0	1	1	1	1	1
Hatchery releases of smolts	0	0	0	0	1	0	0	1
Ecological assessment data								
DEP biological monitoring station	1	0	0	1	1	0	1	1
water quality data	1	1	1	1	1	1	1	1
embeddedness	0	0	1	0	1	0	1	1
Geophysical Factors								
GIS habitat maps	1	1	1	1	1	1	1	1
IFIM data	0	0	0	1	1	1	0	1
Controlled flow	0	0	0	0	0	0	0	1
Totals	**10**	**6**	**6**	**15**	**15**	**8**	**10**	**21**

Slide 11

Dennys Smolt Physiology

- Smolts are physiologically impaired
  - Stocked smolts had significantly reduced enzyme levels within 24 hours
  - Short-term episodic events of low pH/high Al are documented as impeding smolt survival

Slide 12

Smolt Migration Bottle Necks

- Preliminary data from 1997 to 2003 estimate less than 20% survival for 1 parr to smolt
- Dennys River smolt survival from river to outer estuary is estimated at <39%

Slide 13

Water Chemistry

- Baseline chemistry appears not to be a significant threat
- Episodic events occur on all downeast rivers with small tributaries being the most significantly impacted
  - Most frequently in fall and spring
  - 24 hour or greater duration
  - Associated with significant rain events
- The Dennys River is no exception

Slide 14

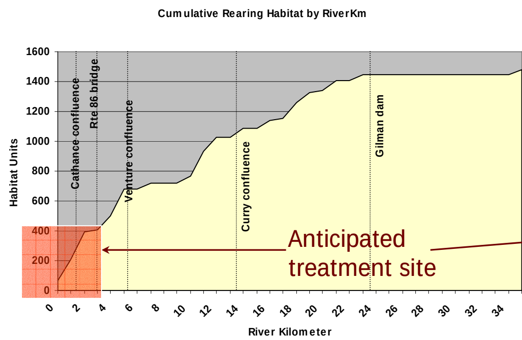
Other drainage selection criteria…

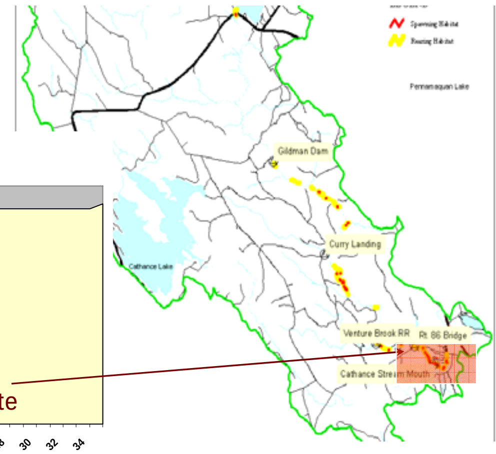
- Proximity of habitat to the estuary
- Quantity of habitat to the estuary
- Drainage size
- Ability to monitor and control flow

Slide 15

Site Selection Process

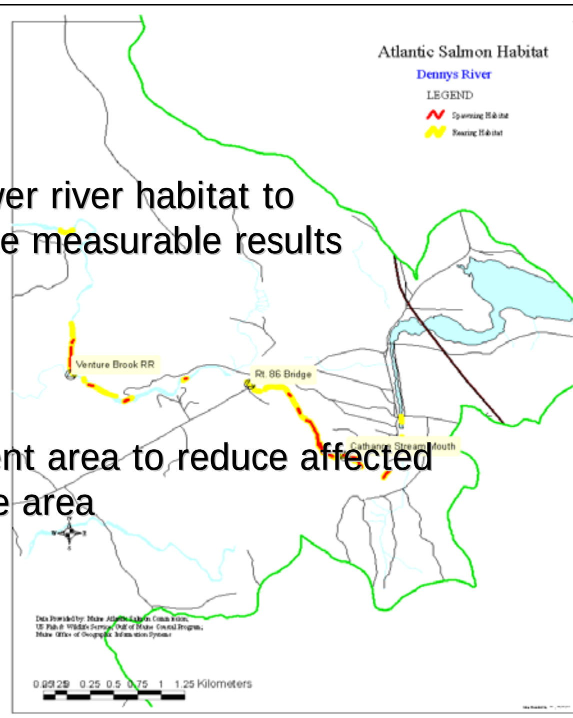
- Habitat features...





Slide 16

- Enough lower river habitat to demonstrate measurable results
- Access
- High gradient area to reduce affected mixing zone area
- Cost



Slide 17

The plan for liming the Dennys

- Apply CaCO3 using a lime doser
- Target episodic events
- Documentation
  - Changes in salmon survival (all life stages)
  - Ecological impacts
    - Invertebrates
    - Water chemistry
    - Fish communities

Slide 18

Why did we select the doser?

Maximum control!!

Slide 19

Pre-assessment monitoring...

- Streamside juvenile salmon rearing study (April-May 2004)
- Invertebrate Survey (ongoing) Partners w/ DEP, ASC, U-Maine Machias
- Flow study (ongoing) Partners w/ USGS, ASC, Dennys River Salmon Club
- Biodiversity survey (summer, 2004)
- Water Chemistry Monitoring (Ongoing) partners w/ U-Maine Senator George Mitchell Center, ASC

Slide 20

Streamside Rearing Study Update

- No escapes
- No natural smolt mortality
- 3 of 1200 fry died
- No vandalism
- Inadvertently captured 3 parr and 1 SMB through intake

Slide 21

Permitting Process

- Law change to allow discharge into a salmon river for the purpose of salmon restoration under the supervision and approval of the Maine Atlantic Salmon Commission (Completed ~April, 2004)
- DEP discharge permit
- ACOE?? *said we did not need one from them though will be asking again to make sure.*
- NEPA
- ESA section 7 consultation
- Town building permit

b) Crooked River, Maine (Project SHARE) – Steven Koening

Slide 1

Crooked River Water Quality Mitigation Project

Presented by
Project SHARE

Slide 2

Slide 3

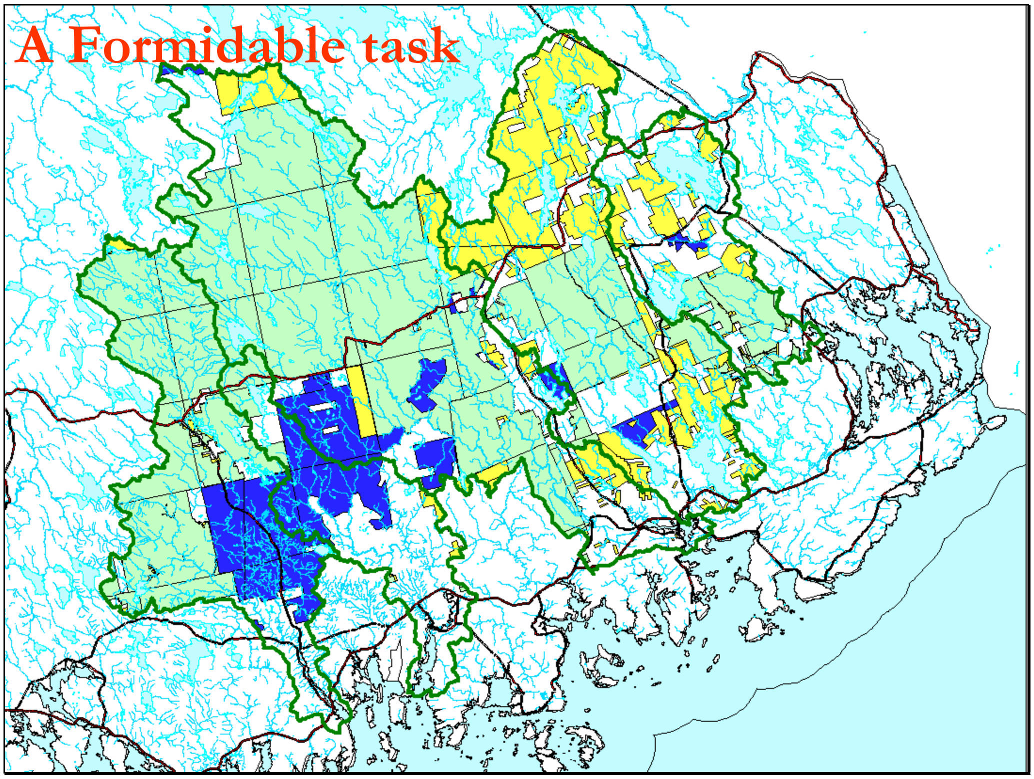
We do not have time to research these fish to extinction.

Slide 4

ASC Chemistry Survey (pH)

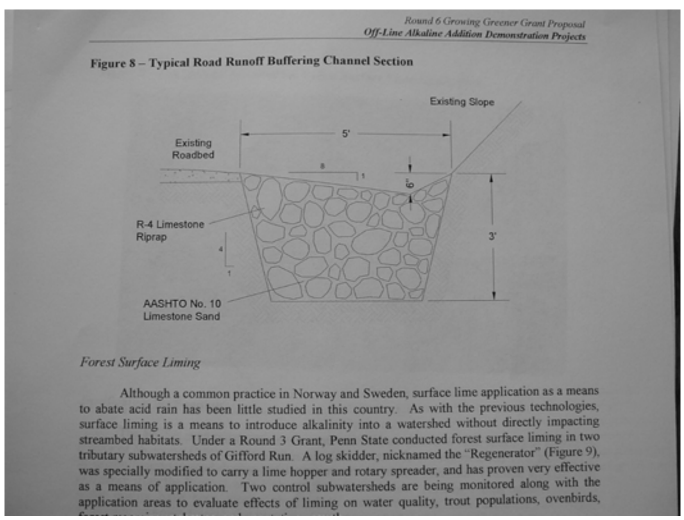
	Spring 2003	Summer	Fall	Spring 2004
Nar Rt 9	6.32	7.44	5.62	6.32
Nar W. Br	5.81	6.72	5.11	5.58
Pleasant weir	5.99	6.76	5.09	5.76
Pleas W. Little	5.42	6.89	4.70	5.40
Dennys Weir	6.38	7.26	5.36	6.13
Cathance flume	6.21	6.44	5.74	6.02
E. Mach North	5.81	7.12	5.17	6.10
Mach Rt 9	5.95	6.92	5.49	6.02
Olds Stream	5.91	6.76	5.52	6.15
Crooked R	5.55	6.71	4.92	5.82

Slide 5



Slide 6

Road Runoff Buffering Channel



Round 6 Growing Greener Grant Proposal
Off-Line Alkaline Addition Demonstration Projects

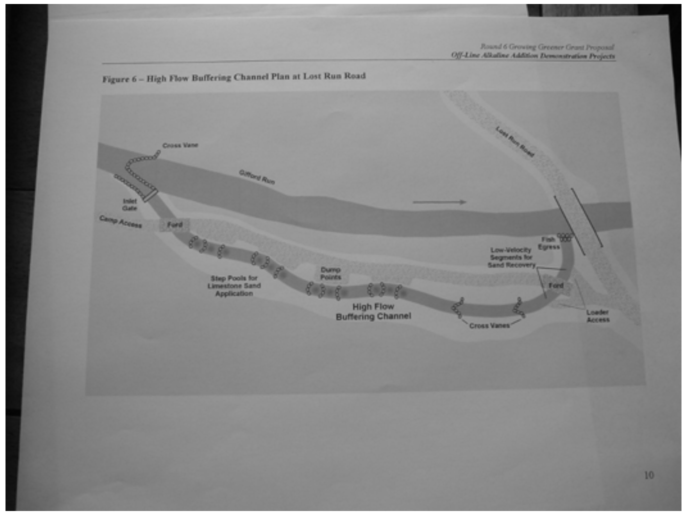
Figure 8 – Typical Road Runoff Buffering Channel Section

Forest Surface Liming

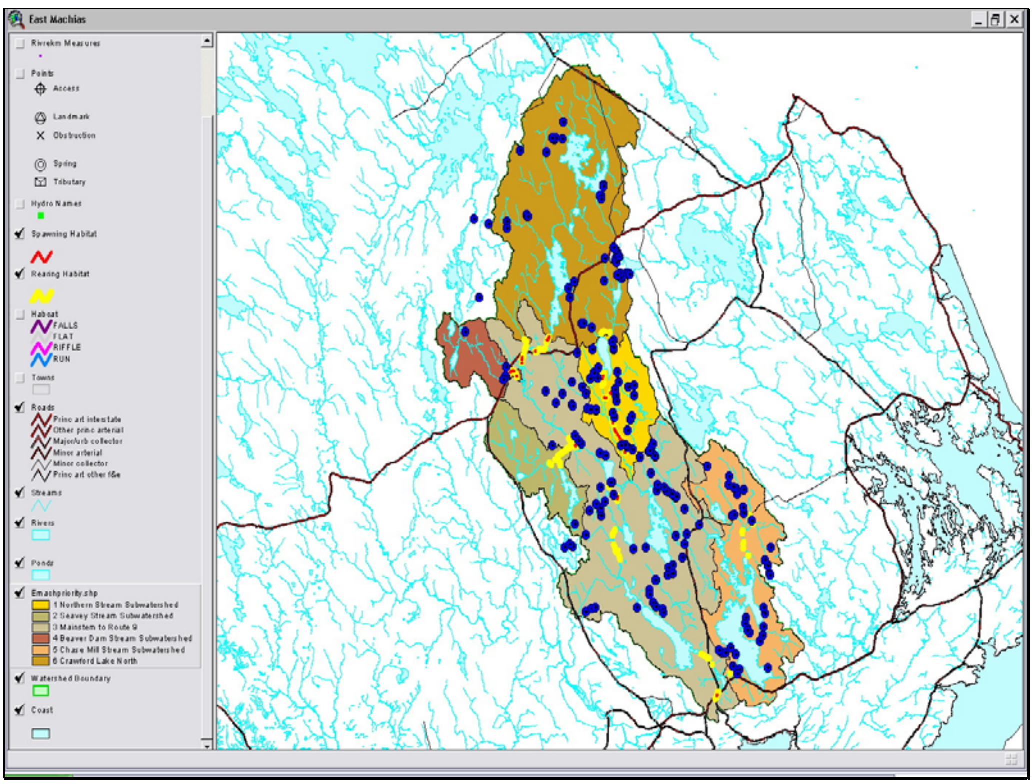
Although a common practice in Norway and Sweden, surface lime application as a means to abate acid rain has been little studied in this country. As with the previous technologies, surface liming is a means to introduce alkalinity into a watershed without directly impacting streambed habitats. Under a Round 3 Grant, Penn State conducted forest surface liming in two tributary subwatersheds of Gifford Run. A log skidder, nicknamed the "Regenerator" (Figure 9), was specially modified to carry a lime hopper and rotary spreader, and has proven very effective as a means of application. Two control subwatersheds are being monitored along with the application areas to evaluate effects of liming on water quality, trout populations, ovenbirds,

Slide 7

High Flow Buffering Channel
$170,000



Slide 8



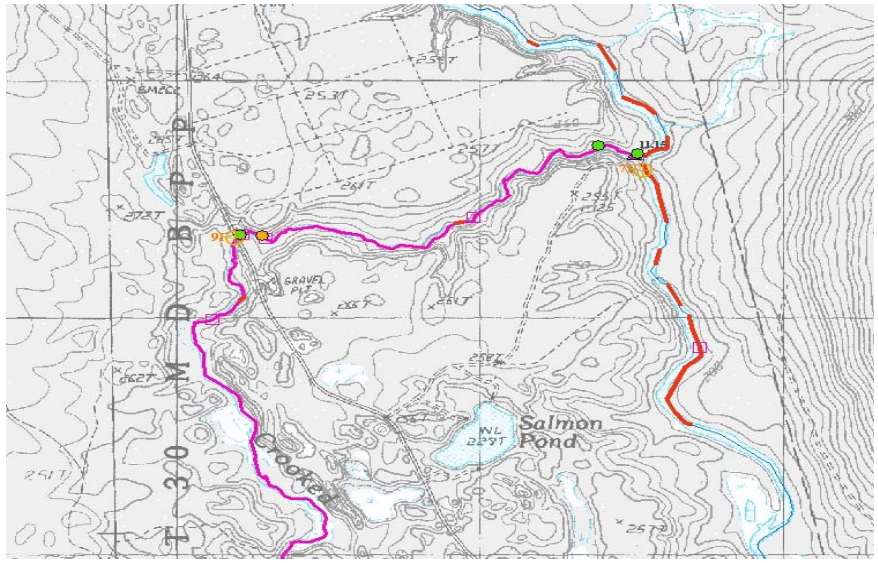
Slide 9

NPS Site Restoration

Slide 10

Slide 11

NPS Sites and Embeddedness



Slide 12

Opportunistic Additions of Limestone to NPS Site Restoration

- Site 1: camp road at confluence. 585’ 11% slope
- Site 2: road 675’ 8% slope to bridge
- Site 3: road crossing restoration
- Site 4: new open bottom arch culvert
- Site 5: Rt 9 ditches draining to brook
- Site 6: terrestrial application to old Rt 9

Slide 13

NPS Restoration Activities - Opportunities

Slide 14

Project Budget

- Limestone riprap 42 yards@$58/yd $2,436
- Limestone sand 51 yards@$48/yd $2,448
- Limestone gravel 248 yards@$48/yd $11,904

(500 tons limestone) $16,788

- Water Chemistry $26,000
- Project Management $2,160

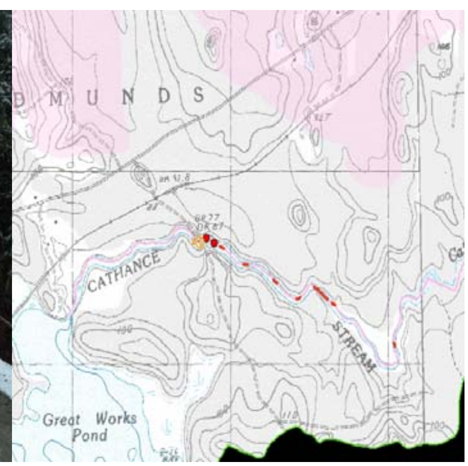
Slide 15

West Branch Narraguagus road approach to culvert

Slide 16

Dodge Road Cathance Stream

Fall 2003 pH 5.74



c) Liming of Acid Waters in Nova Scotia – Wesley White

Freshwater habitat can be protected from acidification by adding alkaline substances (lime) to the water. The usual neutralizing substance is limestone. Most liming products contain calcium, which enhances the beneficial effects of raising pH. Liming has been conducted on a large scale in Europe, the United States and, within Canada, Ontario. The liming effort in Nova Scotia has been insignificant in comparison with the massive programs of the Scandinavian countries. Nevertheless, the importance of the acid threat to the Atlantic salmon of Nova Scotia makes the question of protecting the species there crucial.

When liming was first undertaken in Nova Scotia, it was not generally accepted that acid rain was a major cause of the decline of salmon populations in that province. The liming project was undertaken to demonstrate that raising the pH of an acidified river without performing any other manipulation of the salmon's habitat would cause the salmon population to increase. It was felt that such a demonstration would effectively answer those critics who maintained that the salmon were declining owing to some other cause than acidification.

Liming is a temporary stopgap remedy to acid rain until a permanent solution can be agreed upon. It is not economically feasible to support a salmon fishery by liming but liming can be justified as a genetic preservation program to preserve suitable native stocks with which to restore salmon to rivers after the problem of acid rain has been solved. Any mitigation program that is undertaken will represent a commitment of many decades after acid rain has been reduced to a sustainable level.

The purpose of lake liming is not to enhance lake fisheries, but to protect the Atlantic salmon habitat downstream from the limed lakes. Satisfactory levels of pH can be reached in rivers if headwater lakes are treated with about 2-3 times their acidity. The amount of lime remaining in a treated lake will begin to fall immediately after liming operations are finished as the limed water is replaced by discharges from unlimed tributaries. The duration of satisfactory pH levels depends on the water retention times of the limed lakes. The effects of liming are relatively brief in lakes with short retention times (Figure 1). The retention times of most Nova Scotian lakes are about 3 months so it is obvious that lake liming must be renewed at least annually and preferably just before the swim-up stage in the life cycle of the salmon when they are most sensitive.

When lakes are limed in the summer, the limed water may become overlain by untreated acidic water during the subsequent winter stratification period (Figure 2). If this happens, the benefits of liming will be lost during that winter and the following spring. However, acidification is most severe in the winter and salmon are most sensitive during their late larval stage, which takes place in the spring. Winter lake liming ensures that the surface water has a high pH during these critical seasons. Dissolution efficiency is lower at low winter temperatures (Table 1) but despite this fact, winter became our preferred season for lake liming.

Spreading limestone gravel in the streambed can also treat acid rivers. This is best done by placing gravel bars in stream riffles. Limestone gravel may be unstable during high flows and may obstruct fish migrations. Nevertheless, limestone gravel bars can raise stream pHs, reduce mortalities of salmon and trout and enable these species to recolonise acidified streams for a number of years after their installation. Lacroix (1992) placed a series of small limestone gravel bars in Fifteen-mile Brook, Nova Scotia. The pH of the Brook increased between 0.05 and 0.1 unit over each bar and a total increase of 0.4 units was produced over the entire limed portion of the brook. Calcium increased by 0.4 mg/L. The difference in pH between limed and control and limed areas ranged from 0.01 to 1.31 units. The gravel was not effective during high flows. The pH fell to very low values during high flows in both limed and unlimed areas.

The amount of limestone gravel needed to neutralise an acid river may be very high when flows are high (Figure 3). For example, The Gold River, N.S. has an average flow of about 50 cubic meters/sec. At 0^{o} C, 3500 tonnes of limestone gravel would be required to raise the pH from 4.8 to 5.0.

The turbidity and concentration of suspended solids increase following liming. There may temporarily be a visible plume downstream from newly installed limestone gravel bars in streams or in the wake of boats used in lake liming operations. This effect is short-lived and is normally only detectable with instruments after the liming is completed.

Some liming products may contain toxic metals. Even when this is the case, toxic metal concentrations normally decrease following liming, owing to the decreased solubility of metals at higher pH (Table 2). Aluminum hydroxide may form when clear waters that are high in aluminum are limed. The aluminum hydroxide may then cause some mortality among fish or other aquatic animals. This problem is unlikely to arise in the highly coloured waters of Nova Scotia because the humic substances that cause the high water colour chelate aluminum and prevent the formation of aluminum hydroxide.

Phytoplankton and invertebrates may decline temporarily following liming. Biomass usually recovers but the species composition may be altered and species diversity is usually higher after recovery than before liming. Species eliminated by acidification may take some time to recolonise limed lakes and it may be necessary to reintroduce some species artificially. Fish populations increase after liming of acid waters. Figure 4 shows the response of a population of Atlantic salmon to the liming of East River Chester, N.S. when the pH was raised from 4.8 to above 5.0.

References

Lacroix, G.L. 1992. Mitigation of low stream pH and its effects on salmonids. Environ. Pollut. 78: 157-164.

Watt, W.D. 1986. The case for liming some Nova Scotia Salmon Rivers Wat. Air Soil Pollut. 31: 775-789.

Watt, W.D., and W.J. White 1992. Creating a de-acidified Atlantic Salmon refuge in the East River, Nova Scotia. P 148-164 in Report for 1991 from the Atlantic Region LRTAP Monitoring and Effects Group. B. Beattie ed.

Watt, W.D., G.J. Farmer, and W.J. White. 1984. Studies on the use of limestone to restore Atlantic salmon habitat in acidified rivers. Pp 374-379 *In* Lake and Reservoir Management, proceedings of the third annual conference, Oct 18-20, 1983, Knoxville Tennessee, 604 p.

White, W.J., W.D. Watt, and C.D. Scott. 1984. An experiment on the feasibility of rehabilitating acidified Atlantic salmon habitat by the addition of lime. Fisheries 9: 25-30.

Table 1. Summary of lake liming operations and percent dissolution of lime in Nova Scotia (data from Watt 1986 and Watt and White 1992).

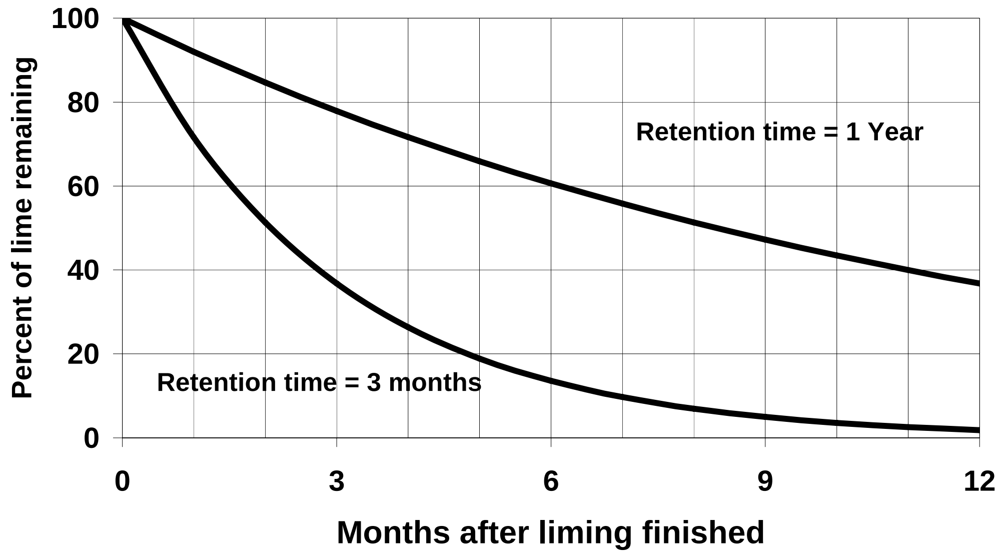
Lake	Type of limestone	Season	Dose (X acidity)	Pre-liming pH	Percent dissolution
Big L.	Dolomite	Summer	0.7	4.6	62
Patterson L.	Dolomite	Summer	2.0	4.4	50
Eastern L.	Dolomite	Summer	2.7	4.6	47
Sandy L.	Calcite	Summer	3.3	4.8	59
Scott L.	Calcite	Winter	8.2	4.5	45
Officers Camp L.	Calcite	Winter	2.5	4.5	49
Timber L.	Calcite	Winter	1.2	5.2	32
Coolen L.	Calcite	Winter	8.2	5.1	34
Square L.	Calcite	Winter	6.3	5.2	32

Table 2. Comparison of pre-liming and post-liming metal concentrations in Sandy Lake, Nova Scotia. (White et al. 1984).

Metal	Pre-liming	Post-liming	Statistical significance[1]
K	0.56	0.56	n.s.
Na	10.91	8.57	n.s.
Al	0.48	0.31	*
Mn	0.25	0.20	+
Fe	0.23	0.45	**
Cu	0.005	0.0006	**
Zn	0.03	0.01	**
Pb	0.002	0.002	n.s.

[1] Student t-test **+** - P<0.05, ***** - P<0.025, ****** - P<0.005, **n.s -** not significant

Figure 1. Decline in lime concentration of lake following liming.



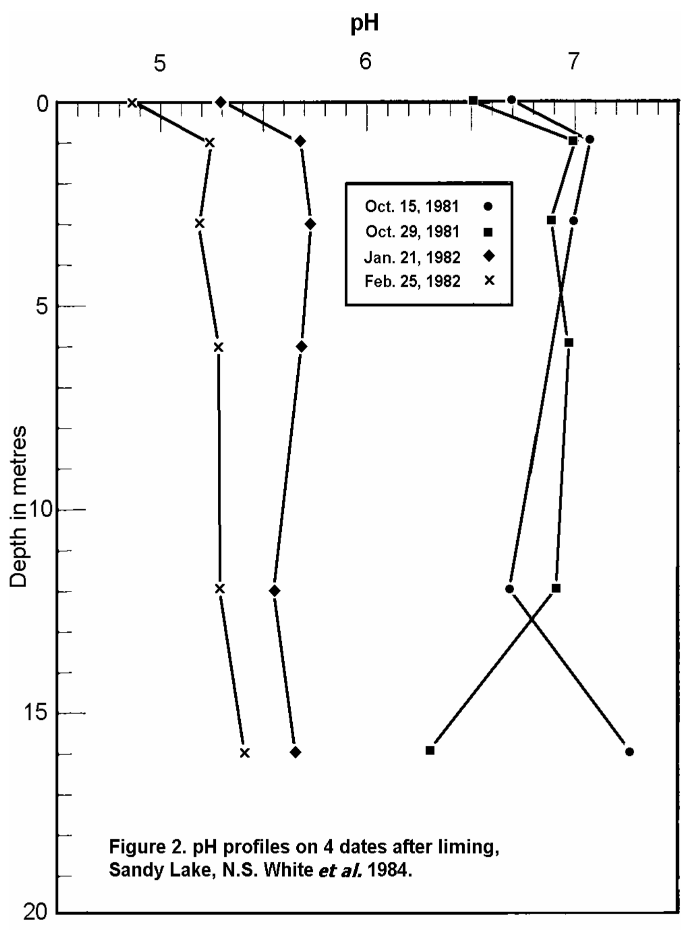
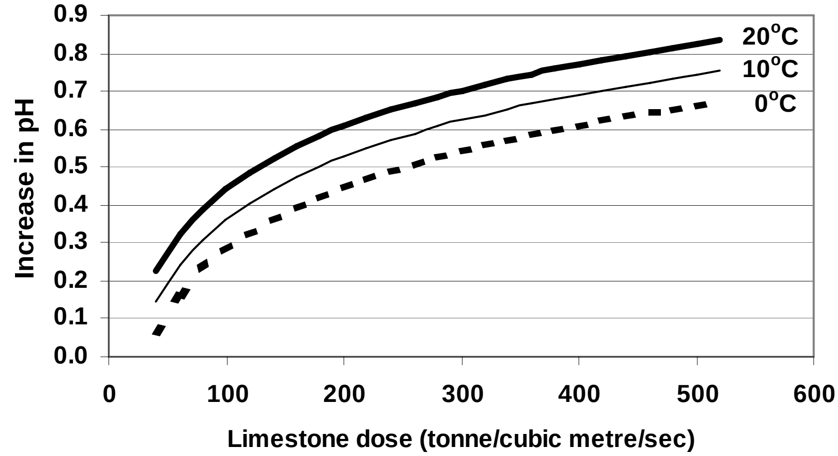


Figure 2. pH profiles on 4 dates after liming, Sandy Lake, N.S. White *et al.* 1984.

Figure 3. Increase in pH with dose using limestone gravel bars. (after Watt *et al.* 1984)



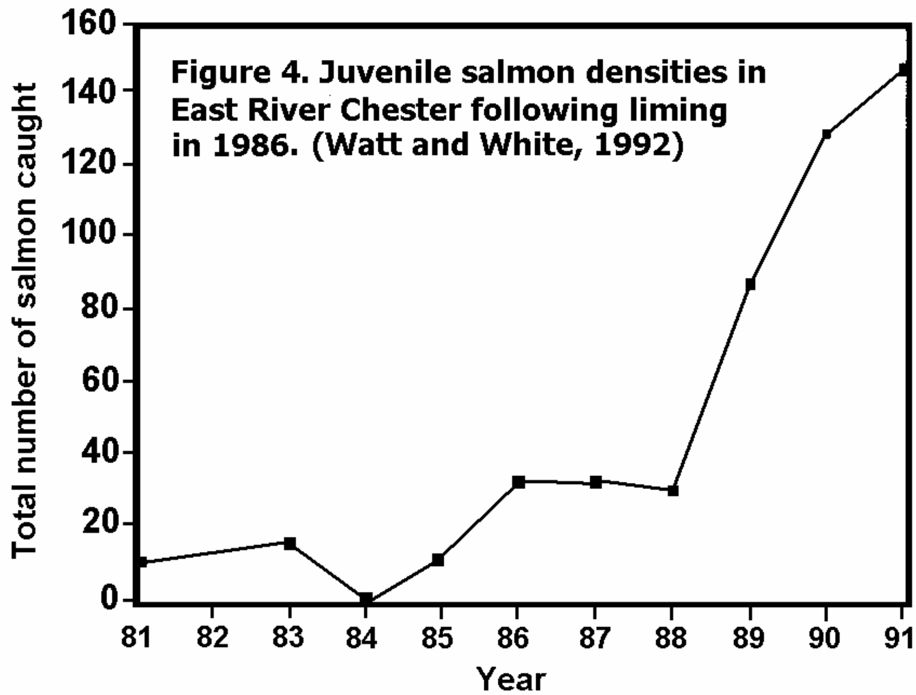


Figure 4. Juvenile salmon densities in East River Chester following liming in 1986. (Watt and White, 1992)

d) Salmon River, Digby, Aquatic, Terrestrial and Agricultural CKD Liming Project – Wesley White for Roland Leblanc

Acid rain is considered to be partly responsible for the disappearance of fish from our lakes and streams. The plume of sulfur dioxide and other acidic substances from industries along Eastern North America, traverses the Metaghan area of Nova Scotia making it the most polluted area in Canada with regard to acid rain precipitation. Nova Scotia receives about 85% of its acid rain from Central Canada and the US mid-west. This has caused acidification of once productive salmon streams. In some cases, stream pH has declined below 4.5. Restocking of these streams would be futile unless stream pH was increased.

The Salmon River Salmon Association applied to the Atlantic Innovation Fund of ACOA, the Atlantic Canada Opportunities Agency, to determine the efficacy of in-stream liming as well as catchment liming of the forest, riparian and agricultural areas on the acidity level of stream waters in sub-watersheds within the Metaghan area. While the effects of direct application of lime to streams and lakes are known to be short lived, there is evidence that the application of lime to riparian zones and agricultural lands adjacent to streams will result in a longer term, sustained supply of basic cations to stream waters through the process of ground water recharge.

Millions of tonnes of cement kiln dust (CKD) are generated annually from cement plants in North America. Although the bulk of the CKD is recycled into clinker dust as a feed stock, approximately 3.35 million tonnes is land filled. Currently the local Lafarge plant produces and landfills approximately 20,000 tonnes of CKD per year which equates to approximately 1/3 of the agricultural lime sold in Nova Scotia. Cement kiln dust is known to be more reactive and more mobile than conventional liming products when used as an amendment for soil acidity on agricultural land in Nova Scotia - in short it works well (Rodd et al. in press). Due to its higher reactivity, it appears that CKD will be the amendment of choice in as far as the beneficial effects of application of lime to riparian and agricultural streamside soils to reduce stream water acidity is concerned. However, the mobility of CKD through acid soils and its subsequent arrival in acidic stream waters has not been studied. We have an opportunity in this pilot study to evaluate the use of Cement Kiln Dust, a by product of cement manufacturing, to remedy the situation of acidified streams in south western Nova Scotia.

Three sub-watersheds will be utilized in this study. On the first sub-watershed, CKD will be applied directly to streams using stationary, in-stream limers. Changes in stream water chemistry and biology, including pH and basic cations, fish numbers and micro and macro vertebrate populations will be monitored at intervals below the limers.

On the other two sub-watersheds, one forestry and the other agricultural, the mobility of CKD through acid soils and its subsequent arrival in acidic stream waters by ground water recharge flow will be studied. Baseline soil pH and cation concentrations will be determined on stream side experimental sites under both forested and agricultural forage land. Extensive soil sampling will be undertaken to determine baseline soil pH, Mechlich III extractable P,K, Ca, Mg, Cu, Na, Mn, Zn and B nutrients. This data will be used to determine the rate (kg/ha) of CKD required to lime these soils to the required pH for optimum forage production in the case of the agricultural soils and optimum tree growth in the case of the forested soils. CKD will be applied in the spring of 2004 at the required rates. After application, changes in soil pH and cation chemistry will be monitored 5 times per year for four years. Soil-water will be sampled 5 times throughout each year at 25 and 50cm at each of the sub-sampling locations and analysed for pH and cations, including heavy metals. Stream water will be monitored for pH, conductivity, dissolved oxygen, turbidity, and temperatures above and below the areas of CKD addition by placing Hydro Lab data loggers above and below the zone of CKD application. Changes in the stream water chemistry (pH, cations, heavy metals) will also be monitored every two weeks by obtaining grab samples upstream and downstream relative to the treated land. This methodology, data collection, collation and interpretation will allow the completion of a comprehensive report after 4 years covering both the scientific discoveries as well as the economic cost of using cement kiln dust as a liming amendment to reduce stream water acidity and improve bio-productivity.

Principal Collaborators:

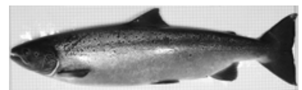
Salmon River Salmon Association:	Roland Le Blanc
Agriculture & Agri-Food Canada:	Keith Fuller, Vernon Rodd, Dale Hebb, Ken Webb
Canadian Forestry Service:	Taumey Mehendrappa
NS Department of Natural Resources:	Kevin Keys
Department of Fisheries and Oceans:	Shayne MacQuaid and Anita Hamilton
Environment Canada:	Ken Doe
NS Dept. Fisheries and Aquaculture:	John MacMillan

e) West River, Sheet Harbour, Trial Liming Project – Shane O'Neil

Slide 1

NS Southern Uplands and Species at Risk

- Water quality and habitat deterioration have placed species at risk
- Atlantic whitefish are now confined to a single watershed
- Southern Uplands salmon are declining precipitously

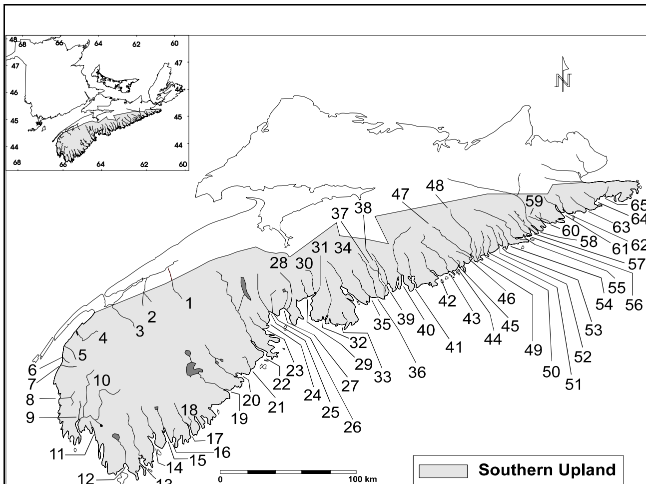


Slide 2

Southern Upland of Nova Scotia and Freshwater Fishery Resources

- Acid precipitation impacts have resulted in losses of most fish populations from several rivers in the Southern Upland
- Recreational and Aboriginal salmon fisheries are closed
- Low marine survival for salmon has accelerated the process

Slide 3



Slide 4

Obstacles to Liming in Nova Scotia

- Public opinion is that the acid rain problem is solved (Clean Air Act)
- Public funds for acid rain mitigation are not available
- Curtailed research/mandate – certainly within Fisheries and Oceans
- Poor understanding of long term effects on terrestrial ecosystem so little corporate support – yet
- Current marine survival for salmon is low so demonstrating positive results will be a challenge

Slide 5

Practical limitations

- The technology is unproven in Nova Scotia
- Long term funding had to be a reality – lake liming through the recreational fisheries agreement was not sustainable
- Limited capability at the outset so project had to "prove itself" to generate support
- Thus a limited scale project to begin with

Slide 6

Joint Project

- Nova Scotia Salmon Association (NSSA) formed an Acid Rain Mitigation Committee to focus mitigation efforts in N.S.
- Key partners/participants in the project:
  - Atlantic Salmon Federation
  - Nova Scotia Power Inc.
  - Trout Nova Scotia
  - Nova Scotia Dept. Agriculture and Fisheries
  - Fisheries and Oceans
  - Environment Canada (Water Quality; CEAA)
    - Advisors: - NS Environment and Labour
      - » Dalhousie Tech Univ.

Slide 7

Project objectives

- Demonstrate that a liming strategy can be an effective tool to mitigate the impacts from acid precipitation in Nova Scotia
- Trial the technology
- Develop the skill and knowledge to apply the technology on a broader basis

Slide 8

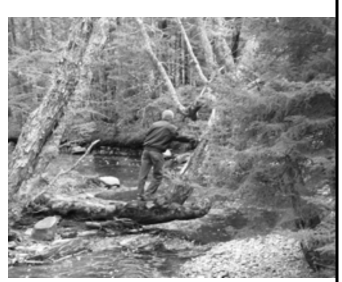
West River, Sheet Harbour, was selected for a trial liming project - Process

- 4 Rivers were selected for study by the NSSA lead Committee, East and West, Sheet Harbour; LaHave and Medway
- NIVA report summarized a liming strategy for each (Hindar 2001)
- The Committee added Gold River after the NIVA report

Slide 9

Complementary projects

- Salmon River Assoc. developed separate mitigation projects
- Small tributary treatment with cement kiln dust (CKD) – Salmon River, Digby
  - Felix Mill Brook
- Terrestrial liming – whole watershed



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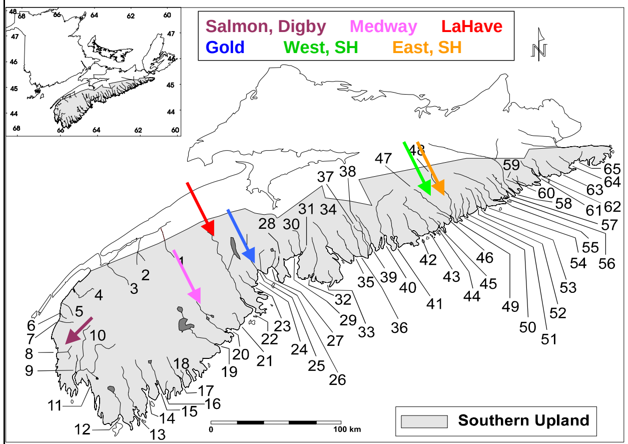
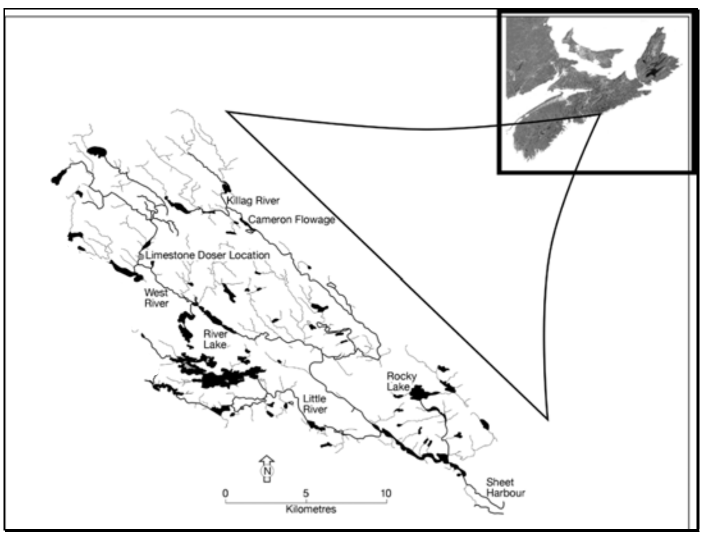


Slide 11

Attributes of West River, Sheet Harbour, for mitigation

- Relatively small watershed – 264km^2
- Two principle tributaries, West and Killag
- pH from mid-1980s to current ranged from 4.8-5.6 depending on seasonal effects

Slide 12



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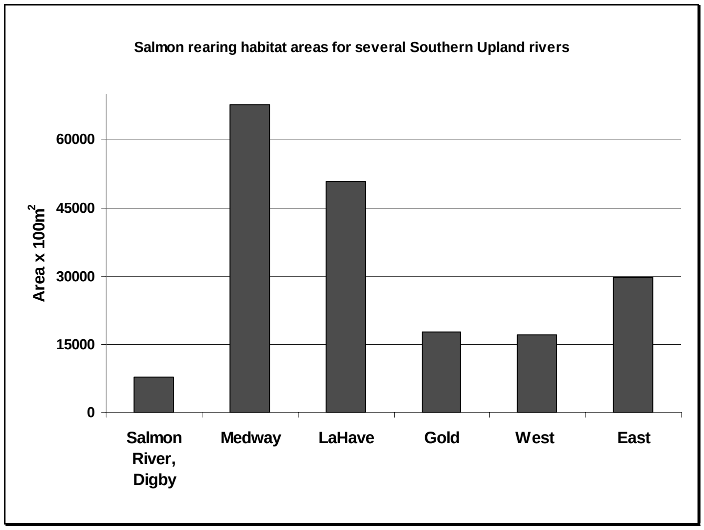

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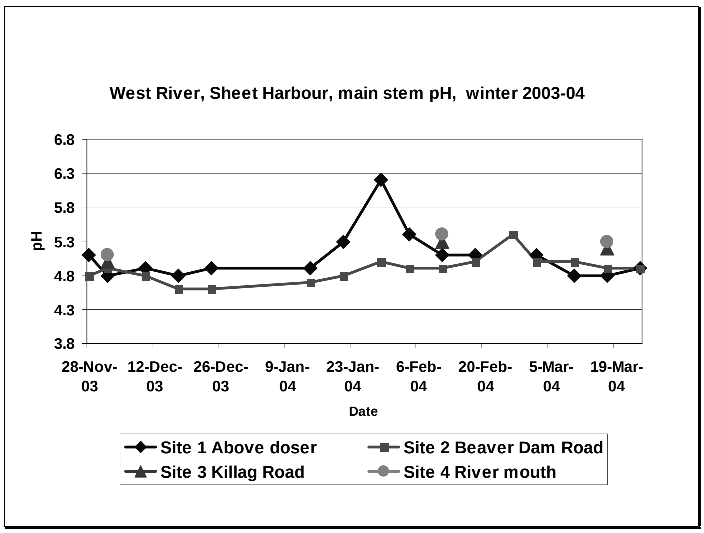

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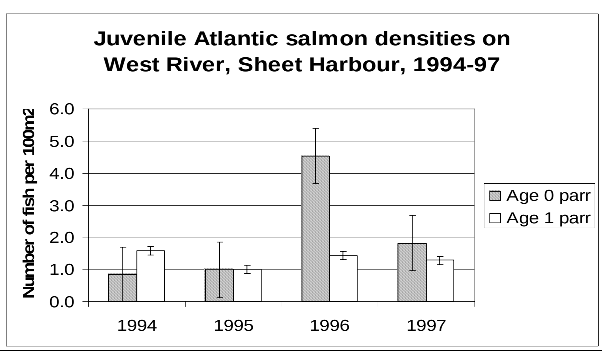
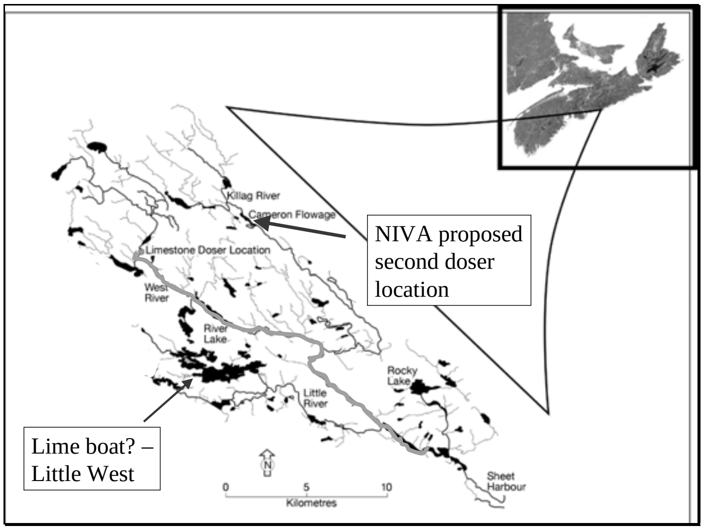
- Salmon angling was closed in 1993 due to low population size
- Juvenile salmon and trout populations are low



Slide 16

- Habitat area for the watershed is 1.7 million m^2
- Main West area treated by doser is 502,600 m^2
- Doser treatment a trial
- Effective watershed treatment would require treating lakes (esp. Little West) and a second doser (as prescribed by NIVA)
- Currently the more optimal pH area in the watershed is the Little West River (12% of habitat area)

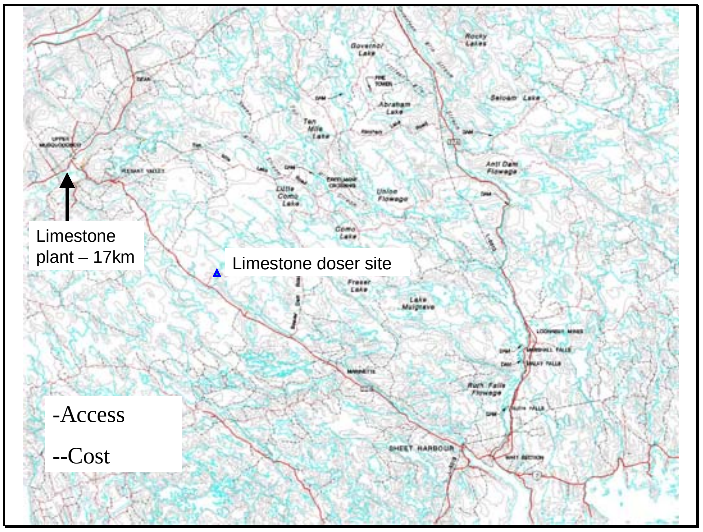
Slide 17



Slide 18

- River treatment with calcitic limestone to adjust the pH to achieve pH 5.5
- Approximately 200 tonnes of limestone required annually

Slide 19



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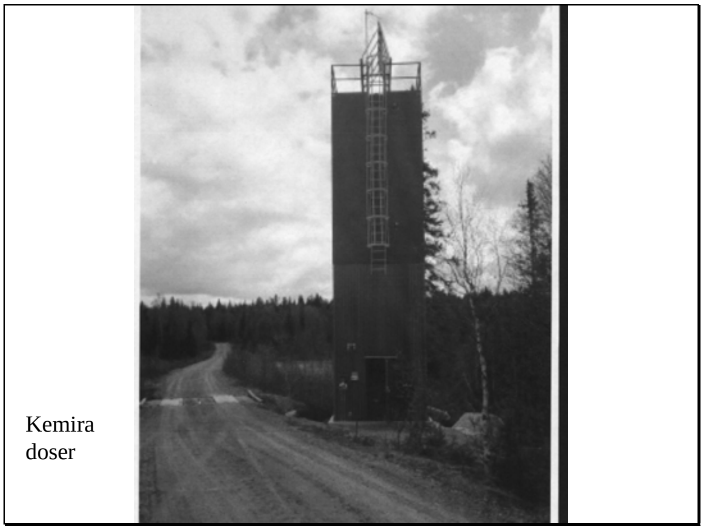

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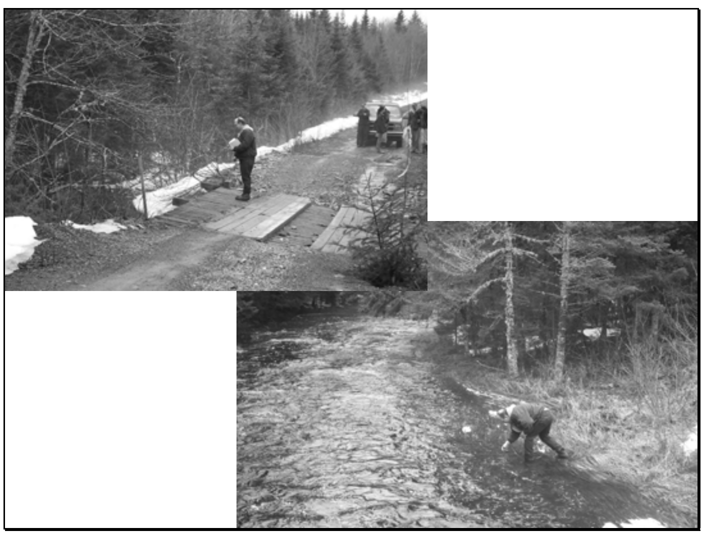


Slide 22

Monitoring

- Water chemistry
  - Sampled weekly at 2 sites through the autumn and winter; monthly at two additional sites throughout the year
  - "Before" sampling began November 2003
- Invertebrate sampling
  - To be done according to the CABIN method in the year before doser installation, in year 1 and again in year 9

Slide 23

Monitoring cont'd

- Fish sampling
  - Will be used as the key indicator to describe improvements in the biota as a result of liming
  - Several sites (number to be determined) will be sampled for all species – lead by NSDAF
  - Before data will consist of available data and sites to be fished in 2004
  - Sampling to occur in year 1 (2005) and bi-annually afterwards.

Slide 24

Timeline and Cost

- Doser site prep. in July 2004 with installation in Sept. and operational by October
- Business plan based on 10-year time frame (2004-2014)
- Subsequent operation subject to assessment given long-term need for mitigation
- Total project cost over the 10-year term ~$700k
- Original outlay is about $225k with annual operating costs in the $35-60k range depending on the year.
- Additional in-kind; some of anticipated costs may also be in-kind

GENERAL DISCUSSION

A lively discussion ensued on the ‘core problems’ for Atlantic salmon, i.e., low abundance in the southern extremity of their range caused by low at-sea survival, compounded in some locales by acid rain limiting production in fresh water. Live salmon gene banks and alternate generation captive production of adults from wild parr/smolts are being used to minimize the loss of genetic diversity and maintain vanishing populations by circumventing the marine phase of their life cycle; in-stream liming is being proposed to restore critical freshwater habitat of important salmon populations and their ecology in isolation from the issue of life cycle closure. One observation was that liming of rivers in the name of salmon is a costly and long-term (up to 50 years) venture, that, at present sea survival, will yield little if any gain to salmon populations. Such efforts by salmon advocacy groups may draw financial resources away from possible support of risk-managed biodiversity facilities or research that might address low sea survival of endangered or nearly endangered salmon populations.

One suggestion was to consider shorter-term “pilots studies” to demonstrate the ecological benefits of liming, e.g., the low cost/technology of liming of an East River Sheet Harbour NS headpond/flowage which could, with improved acidity, potentially demonstrate the restoration of an entire community of fishes including the alewife, and its potential to increase productivity through the importation of marine nutrients. Others were of the opinion that the most important aspect of a pilot project was to demonstrate the rehabilitation of water conditions to what they were, i.e., the ions should be enough to fuel a public policy/action plan to accelerate the ecological recovery of acidified waters and their productivity.

There was general consensus that governments needed to take responsibility/develop policy to better reduce emissions and combat and possibly hasten the long-term natural restoration of acidifed waters and watersheds, i.e., the loss of productivity is broad-based and encompasses forestry, agriculture and fisheries sectors. Suggested revenue sources for such undertakings were the industries that contributed to the problem. To accomplish this there is a need to increasingly profile the issue that the Clean Air Act has helped reduce emissions but will not result in the recovery of many watersheds in ours or our children’s life time.

Following this discussion, Dave Meerburg and Dr. Fred Whoriskey led the group in a consensus-oriented extraction of key elements made during the preceding 1.5 days (following page).

SUMMARY OF KEY ELEMENTS

- Acid rain, resulting from emission of pollutants from industrial areas of North America, is a serious problem associated with the premature mortality of wild Atlantic salmon and extirpation of some populations.

- Acid rain induces changes to water chemistry, which results in the loss of ions across the salmon's gill epithelium and ultimately, death due to the failure of the circulatory system. Smolt and fry are the most sensitive stages of young salmon. Mortality in salmon is believed to be due to difficulty in transition of juvenile salmon from freshwater to the marine environment.

- Acid rain has adversely affected the survival of threatened and endangered populations of wild Atlantic salmon, especially in the Southern Upland of Nova Scotia (Canada) and in eastern Maine (USA), respectively.

- Liming of watersheds and watercourses is recognized as an acidification mitigation technique that provides benefits to salmon and other species (terrestrial and aquatic), as well as for forestry and agriculture. In Nova Scotia, the Nova Scotia Salmon Association is piloting a river liming mitigation project on the West River, Sheet Harbour. In Maine, NOAA Fisheries is designing a liming project for the Dennys River. Both projects involve several partners.

- There is no clear government policy within Canada and the USA as to the responsible agencies for action to mitigate losses of Atlantic salmon stocks by liming rivers and watersheds in acid rain impacted areas.

- Gene banks offer supportive rearing and breeding to maintain genetic diversity of a salmon population through periods of critically low abundance. Live gene banks can be conducted in designated parts of a river or complete river that still has natural reproducing populations as special refuges, in limed sections of acidified rivers where remnant stocks can sustain themselves or in captivity.

- There are several diverse public interest groups seeking resolution of the problems resulting from acid rain. Governments and the public need to be aware of this and support remedies to address this issue.

- The North American Commission of NASCO may provide this forum to enable discussion of progress on the acid rain issue as it affects salmon, as none other seems to exist, at this time.

The way forward:

- Governments need to adopt policy and programs to reduce and eliminate acid rain causing emissions and to support mitigation of the impacts of acid rain.

- Cooperation among those interested in resolving acid rain issues and partnerships is important to effectively address the problem. It is especially important to further research the ecological impact and cost effectiveness of stream and watershed liming techniques as mitigative measures and to share information and findings among the government, NGO and industry stakeholders.

Government, NGO and industry stakeholder partners should develop a strategy and action plan to elevate pubic awareness to build support for acid rain abatement and mitigation initiatives.

An ecosystem approach to addressing the acid rain issue is essential to enable effective action and to build public support groups.

- Funding needs to be found to support mitigation technologies; preferably in collaboration with those causing the acidic precipitation.

REPORT PRESENTED TO NASCO ON IMPACTS OF ACID RAIN ON SALMON

9.1 Representatives of the United States and Canada presented a report on cooperative work between the two countries on acid rain, including the results of a workshop, jointly sponsored with the Atlantic Salmon Federation, held in April 2004, NAC(04)9 (Annex 4).

9.2 The Secretary questioned why it could take 50 years or longer to re-establish natural buffering capacities in some rivers. A representative of Canada explained that some watersheds have no buffering capacity left. When this is the case, it takes many years to recover that buffering capacity and for pH to be improved sufficiently. He explained that acid rain has a chronic impact in rivers of Southwest Nova Scotia where the geology does not provide sufficient buffering.

9.3 The Chairman asked how often pH levels in North American rivers are monitored. A representative of Canada replied that Canada used to have an acid rain programme that actively monitored Canadian rivers. This programme gave a good indication of impacted rivers. He noted that funding ended several years ago and, consequently, pH levels of Canadian rivers are no longer checked regularly**.**

9.4 A representative of the United States commented that, unlike in Southwest Nova Scotia, high acidity is not a chronic problem in the United States. The problem in Maine is more episodic following snow melt and heavy rains. Salmon rivers in the United States still maintain some natural buffering capacity. He also noted that the United States is making an effort to improve its water quality monitoring programme on rivers in Maine with Atlantic salmon populations.

9.5 The Parties welcomed the report and noted the value of the workshop. The representative of the United States stated that NASCO provides an excellent forum for information exchange on issues such as this one. **Given the general interest in this matter and the wide-ranging expertise among members of NASCO, she endorsed the recommendation in NAC(04)9 to include acid rain on the Council agenda next year and into the future. The representative of Canada concurred**. As recommended in NAC(04)9, **the Parties also agreed to continue their cooperative work on acid rain issues and to report back to the NAC in 2005** on the progress of this cooperation, including the status of their pilot liming projects.

Appendix 1. List of Participants

NAME	ORGANIZATION	ADDRESS	E_MAIL
Dan Kircheis	NOAA	Orono, Me	Dan.Kircheis@noaa.gov
Pat Scida	NOAA	Orono, Me	Pasquale.Scida@noaa.gov
Richard Dill	Maine ASC	Orono, Me	Richard.dill@maine.gov
Steven Koenig	Project Share	Eastport, Me.	skoenig@salmonhabitat.org
Atlee Hindar	Norwegian Institute for Water Research	Grimstad, Norway	Atle.Hindar@niva.no
Tom Clair	Environment Canada	Sackville, NB	ClairTomEC@dfo-mpo.gc.ca
Lisa DeBaie	Environment Canada	Dartmouth, NS	Lisa.DeBaie@ec.gc.ca
Karen Potter	ACAP- EC	Dartmouth, NS	Bacap6@ns.aliantzinc.ca
Lowell DeMond	LaHave River Salmon Association	Bridgewater, NS	Lowell.demond@ns.sympatico.ca
George Ferguson	NSSA Acid rain Committee	Sackville, NS	nssa@ns.sympatico.ca
Fred Whoriskey	Atlantic Salmon Federation	St. Andrews, NB	asfres@nbnet.nb.ca
Lewis Hinks	Atlantic Salmon Federation	Chester, NS	Lhinks@auracom.com
Stephen Chase	Atlantic Salmon Federation	St. Andrews, NB	n6schase@nb.aibn.com
John Burrows	Atlantic Salmon Federation	Brunswick, ME	asfjb@blazenetme.net
Danny Bird	Atlantic Salmon Federation	St. Andrews, NB	DBird@nbnet.nb.ca
Ralph Heighton	Nova Scotia Dept Agriculture and Fisheries	Pictou, NS	HeightOR@gov.ns.ca
Mallory Gilliss	New Brunswick Dept of Environment & Local Government	Fredericton, NB	Mallory.Gilliss@gnb.ca
Ken Meade	Nova Scotia Power	Halifax, NS	Ken.Meade@nspower.ca
Wesley White	Consultant	Halifax, NS	Wesleyw@ns.sympatico.ca
Larry Marshall	DFO Science, BIO	Dartmouth, NS	MarshallL@mar.dfo-mpo.gc.ca
Shayne McQuaid	DFO Habitat Stewardship, BIO	Dartmouth, NS	McQuaidS@mar.dfo-mpo.gc.ca
Peter Amiro	DFO Science, BIO	Dartmouth, NS	AmiroP@mar.dfo-mpo.gc.ca
Shane O'Neil	DFO Science, BIO	Dartmouth, NS	OneilS@mar.dfo-mpo.gc.ca
Kats Haya	DFO Science, SABS	St. Andrews, NB	HayaK@mar.dfo-mpo.gc.ca
Dave Meerburg	DFO Science, Science	National Capital Region	Meerburd@dfo-mpo.gc.ca
Tim Young	DFO International	National Capital Region	YoungT@dfo-mpo.gc.ca

Appendix 2. Letter of Invitation

Fisheries and Oceans Canada Pêches et Océans Canada

Dear all,

Many of you are aware of the above titled workshop scheduled for Monday, April 19 - Tuesday April 20, in St. Andrews, New Brunswick. This Workshop is in response to a commitment by Canada at the 2002 meeting of the North Atlantic Salmon Conservation Organization (NASCO) to consider with the United States, "the causes, effects and mitigation options of acid rain". The DFO Maritimes Region of Canada considered these points in a Regional Assessment [DFO. 2000. The effects of acid rain on Atlantic salmon of the Southern Upland of Nova Scotia, DFO Maritimes Regional Habitat Status Report 2000/2E 19p.]; the United States has similarly covered much of the same ground [e.g., Arter, B. 2003. Status and trends of water chemistry in Maine Atlantic salmon watersheds - A report on the conference findings and round table discussion for Project Share Research and Management Committee. 15p.]. Minutes from the 2003 meeting of NASCO indicate that the United States is now more interested in "reaching out to experts in other countries relative to developing and implementing mitigation measures".

To this end I have been tasked by the Regional Director General, Maritimes Region, to organize with the US and facilitate with the Atlantic Salmon Federation, a workshop that would serve our mutual interests. Therefore we have been developing an agenda in consultation with several of you, that will focus on the goals, feasibility, prioritization of approaches, possible direction and in particular, the experiences and associated technology. We hope to have a cross section of experts, including Atle Hindar who is expected to be in the area.

Neither the draft agenda and mailing list, nor personal contact (by Shayne McQuaid, Dan Kircheis or myself) with several of you are as yet complete. This will come later in the week. With time being of the essence, I am hoping however that this thumbnail sketch and "heads-up" will be sufficient for you to circle the dates on either your or your representative's calendar.

The Workshop has essentially no operating budget and so therefore you are responsible for making and paying for your attendance. Accommodations are available at the Fairmont Algonquin, St. Andrews at a special rate of $99 +tax Cdn [1-800- 441-1414 identify yourself against the block of rooms held to March 19 under "DFO/ Diadromous Fish Division"]; more economical accommodations may be found at the St. Andrews Motor Inn 1-506-529-4583. The Algonquin offers a restaurant (not inexpensive); the Motor Inn does not. Both are within walking distance of what few restaurants may be open in April. The Workshop will take place in the Atlantic Salmon Federation's Conference Center at Chamcook, just a few miles NE of town (directions to follow later).

I hope that many of you or your designates can participate and will notify me of same. For those of you that have not yet been contacted re: your anticipated formal contribution on the agenda (or in some cases from the floor) I will be in touch! Thank you.

Larry

PS-Should you have questions please do not hesitate to contact me.

Appendix 3. Agenda (Tentative)

<u>April 19</u>

9:00-9:20 am: Welcome, introductions and introductory remarks (Marshall/ Kircheis)
Review of agenda

9:20-10:00 Policy & role of government in mitigating acidification
a) Maine - Kircheis
b) Canada - Timoffee

10:00-10:30 Break

10:30-11:30 Impact of acid rain on Atlantic salmon and their habitat
a) Maine (Dill)
b) Maritimes Region (Amiro)

11:30-12:00 Acid rain update
i) Emission trends, current efforts to reduce acid rain in US (Kahl)

12:00-13:00 Lunch (provided)

13:00-13:30 Acid rain update
ii) Emission trends, current efforts to reduce acid rain in Canada (Timoffee/ Chase)

13:30-14:00 Water chemistry trends in Maine (Kahl)

14:00-14:30 Water chemistry trends in Atlantic Canada and projections for recovery (Clair)

14:30-15:00 Summary of approaches to mitigation in published North American work (Clair)

15:00-15:15 Break

15:15-16:30 The Scandinavian experience: philosophy, policies, major programs, successes and problems (Hindar)

16:30-17:00 An approach to prioritizing acid-impacted salmon populations for recovery initiatives (Amiro)

17:00-20:30 Supper break (Burrows for info)

20:30- 22:30 Mixer : informal presentations (O'Neil - Convener)

<u>April 20</u>

08:30-9:45 Mitigation: summary/ overview of recent/ current and planned *projects*; their objectives/ results and conclusions re: potential for mitigation

a) US (Koenig) a) US
   - i) Pilot liming initiative in Maine (Kircheis)
   - ii) NGO planned initiatives to address water chemistry threats in Maine (Koenig)

b) Canada
   - i) Past lake and river liming (White)
   - ii) NGO planned initiatives (CKD/ limestone/ stream and watershed) (O'Neil/ Fuller)

9:45-10:00 Break

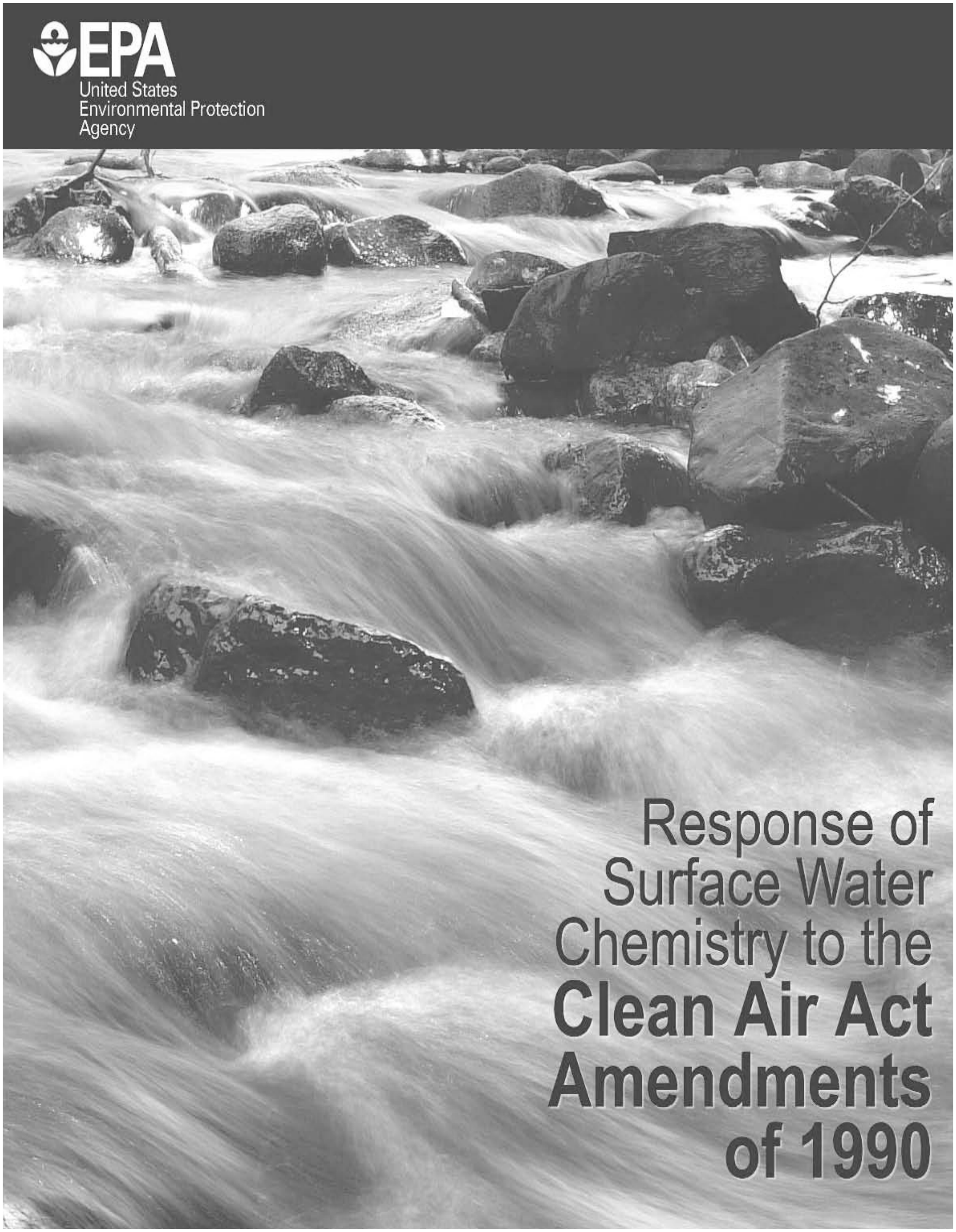
10:00-11:30 Beyond the *projects*: e.g., general discussion on perceived utility/ goals & feasibility of extending the projects [or other forms of mitigation] to *programs*; triaging the needs and approaches, identifying the role of GOs & NGOs; merits of interregional consultation/ collaboration.(Whoriskey)

11:30-12:00 Workshop Summation: key elements and wording for inclusion in the Proceeding's Executive Summary (Meerburg/ Chase/ Marshall)

12:00 Lunch (provided)

Adjournment

Appendix 4. Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990.



Response of surface water chemistry to the Clean Air Act Amendments of 1990

John L. Stoddard[1], Jeffrey S. Kahl[2], Frank A. Deviney[3], David R. DeWalle[4], Charles T. Driscoll[5], Alan T. Herlihy[6], James H. Kellogg[7], Peter S. Murdoch[8], James R. Webb[9], and Katherine E. Webster[10]

[1]Western Ecology Division U.S.
Environmental Protection Agency
200 SW 35th Street Corvallis, OR 97333 Stoddard.John@epa.gov

[2]Senator George Mitchell Center
102 Norman Smith Hall University of Maine
Orono, ME 04469 Kahl@maine.edu

[3]Department of Environmental Sciences
Clark Hall University of Virginia
Charlottesville, VA 22903

[4]Pennsylvania State University
106 Land and Water Research Bldg.
University Park, PA 16802

[5]Dept. Civil & Environmental Engineering
Syracuse University Syracuse
NY 13244-1190

[6]Oregon State University
c/o U.S. EPA 200 SW 35th Street
Corvallis,OR 07333

[7]Dept. Environmental Conservation
Water Quality Division
103 South Main Street
Waterbury, VT 05671-0408

[8]U.S. Geological Survey
425 Jordan Road
Troy, NY 12180

[9]Department of Environmental Sciences
Clark Hall University of Virginia
Charlottesville, VA 22903

[10]Department of Biological Sciences
Murray Hall University of Maine
Orono, ME 04469

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EXECUTIVE SUMMARY

Response of surface water chemistry to the Clean Air Act Amendments of 1990

SEPTEMBER 30, 2002

Purpose of this report. Title IV of the 1990 Clean Air Act Amendments (CAAA) set target reductions for sulfur and nitrogen emissions from industrial sources as a means of reducing the acidity in deposition. One of the intended effects of the reductions was to decrease the acidity of low alkalinity waters and thereby improve their biological condition. *The purpose of this report is to assess recent changes in surface water chemistry in the northern and eastern U.S., in response to changes in deposition.* The regions covered in this report are New England (sites in Maine, New Hampshire, Vermont and Massachusetts), the Adirondack Mountains of New York, the Northern Appalachian Plateau (New York, Pennsylvania and West Virginia), the Ridge and Blue Ridge provinces of Virginia, and the Upper Midwest (Wisconsin and Michigan). The data covered in this report are from 1990 through 2000, the period since the last major science review by the National Acidic Precipitation Assessment Program (NAPAP).

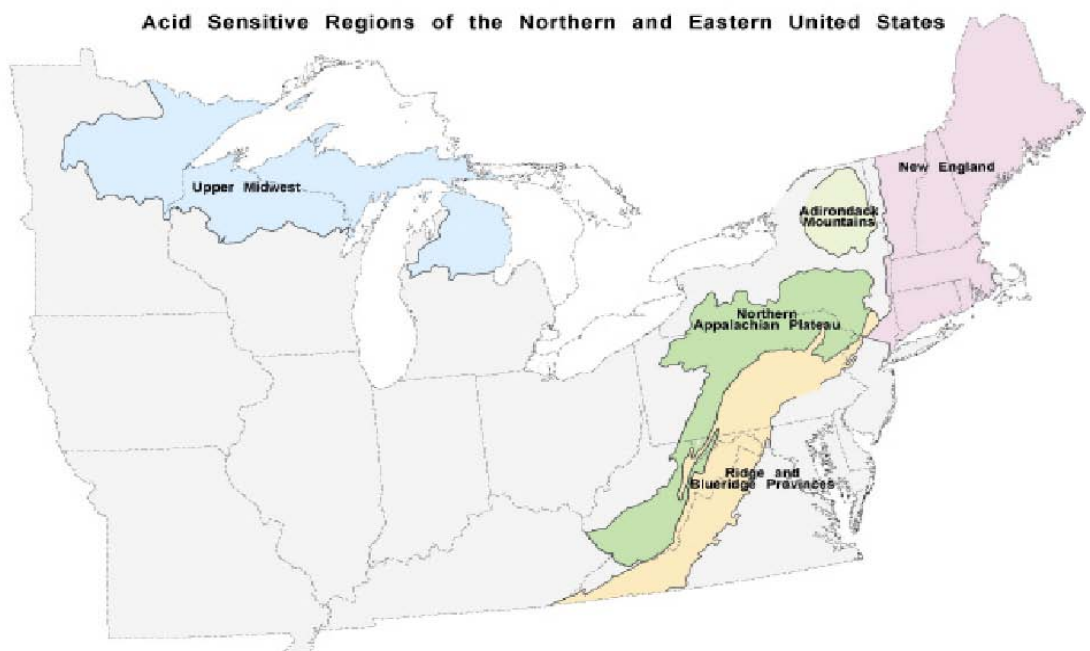


Figure A. Acid sensitive regions of the northern and eastern United States; this report assesses trends in surface waters in each of these regions.

Substantial reductions in emissions of sulfur have occurred in the past 30 years, with the rate of decline accelerated by Phase I of the 1990 CAAA, implemented in 1995. Modest reductions in nitrogen emissions have occurred since 1996. The key questions are a) whether the declines in emissions translate into reductions in acidic deposition; and b) whether biologically-relevant water chemistry has improved in acid sensitive regions. The measures of expected 'recovery' include decreased acidity, sulfate, and toxic dissolved aluminum concentrations.

Anthropogenic acidity in atmospheric deposition. NOx and SOx from the combustion of fossil fuels react with water in the atmosphere to produce 'acid rain', a dilute solution of nitric and sulfuric acids. This acidity (and the acid anions sulfate and nitrate) may travel hundreds of miles before being deposited on the landscape. The northern and eastern U.S. receives precipitation with mean pH that ranges from 4.3 in Pennsylvania and New York, to 4.8 in Maine and the Upper Midwest. The acidity (hydrogen ion concentration) in precipitation in the eastern U.S. is at least twice as high as in pre-industrial times. Atmospheric deposition is one of the most ubiquitous non-point sources of chemicals to ecosystems.

Acid-base status of surface waters. The 1984-86 EPA National Surface Water Survey (NSWS) estimated the number of acidic waters at 4.2% of lakes and 2.7% of stream segments in acid-sensitive regions of the North and East. 'Acidic' waters are defined as having acid neutralizing capacity (ANC) less than zero (i.e. no acid buffering capacity in the water), corresponding to a pH of about 5.2.

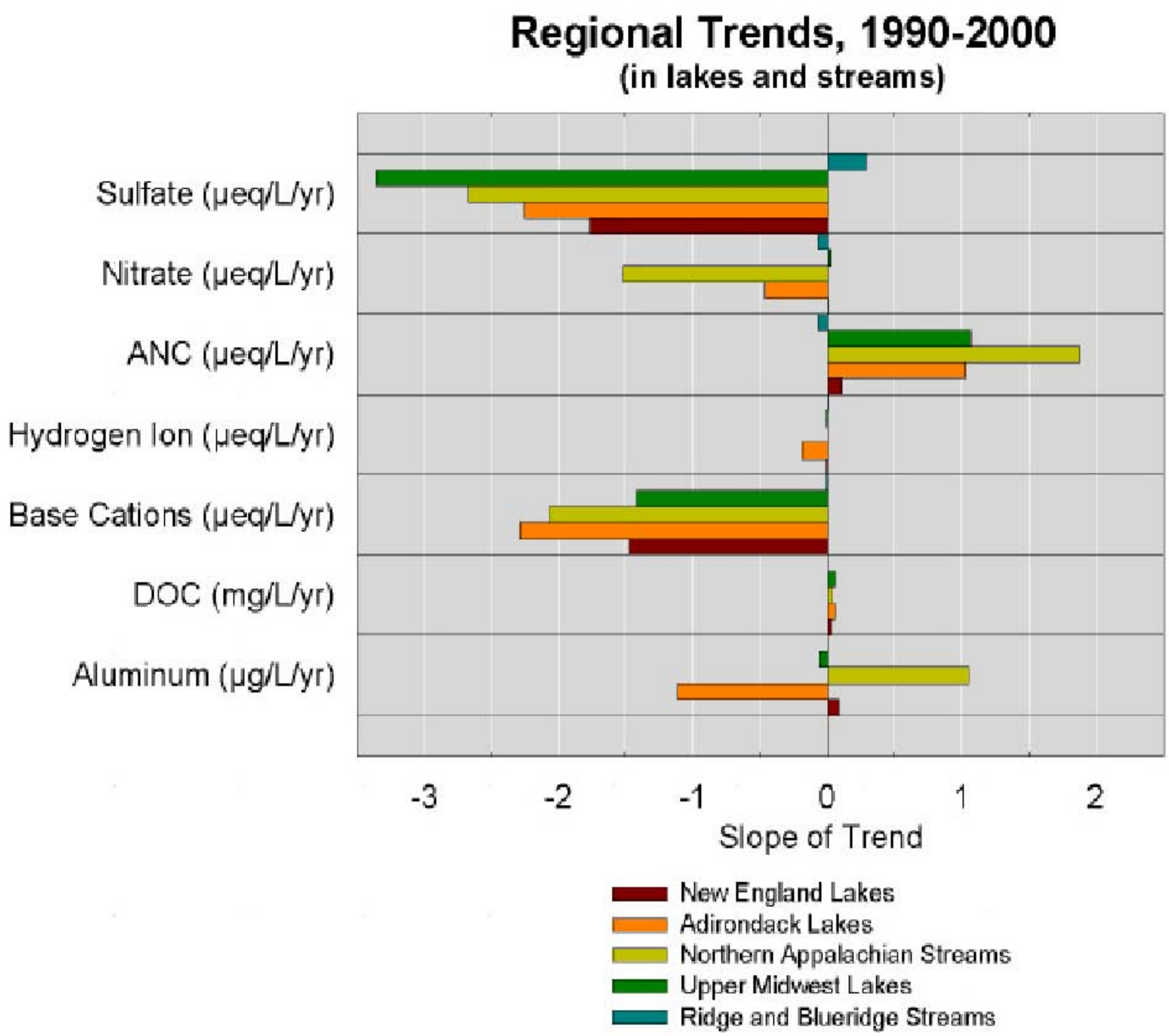
This report addresses the recent chemical responses in the surface waters in five regions of the North and East that are considered sensitive to acidic deposition. The data in this report are largely from the EPA Long Term Monitoring (LTM) and the EPA Temporally Integrated Monitoring of Ecosystems (TIME) projects, part of EMAP (Environmental Monitoring and Assessment Program). The regions include lakes in the Adirondacks, central and northern New England, and the upper Midwest. Sensitive regions with small streams are found in the mid-Atlantic region, including the northern and central Appalachian Plateau and the Ridge and Blue Ridge provinces. Surface waters in most other regions are not sensitive to the impacts of acidification due to the nature of the local geology.

Recent changes in atmospheric deposition. We evaluated the changes in atmospheric deposition from the five regions during 1990-2000, using National Atmospheric Deposition Program (NADP) data. Sulfate declined significantly at a rate between -0.75 and -1.5 µeq/L/year. There was a sharp drop in sulfate concentrations in 1995 and 1996, followed by a modest increase in 1997-2000, in parallel with emissions. Nitrogen (nitrate + ammonium) declined slightly in the Northeast, and increased slightly in the Upper Midwest; most of these changes can be attributed to changes in nitrate deposition. Base cations in deposition, which are important for the neutralization of acidity in precipitation and in watersheds, showed no significant changes during the decade in the East, and increased slightly in the Upper Midwest. These changes in deposition are a continuation of trends that pre-date the 1995 implementation of Phase I of the CAAA, and are consistent with other recent published analyses of changes in regional deposition patterns.

Recent changes in acid base status in surface waters. All regions except the Ridge/Blue Ridge province in the mid-Atlantic showed significant declines in sulfate concentrations in surface waters, with rates ranging from -1.5 to -3 µeq/L/year (Figure B). These declines were consistent with the decline in sulfate in precipitation. Nitrate concentrations decreased in two regions with the highest ambient nitrate concentration (Adirondacks, Northern Appalachian Plateau), but were relatively unchanged in regions with low concentrations. Dissolved

Organic Carbon (DOC) increased in each region, potentially contributing natural organic acidity to offset the recovery from decreased acidity and sulfate in deposition.

Acid neutralizing capacity is a key indicator of recovery, as it reflects the capacity of watersheds to buffer inputs of acidity. We expect increasing values of either ANC, pH, or both, in response to decreasing deposition of sulfur and nitrogen from the atmosphere. ANC increased in three of the regions (Adirondacks, Northern Appalachian Plateau and Upper Midwest) at a rate of +1 to +2 μeq/L/year, despite a decline in base cations (calcium + magnesium) in each region (Figure B). The decline in base cations offsets some of the decline in sulfate, and thus limits the increase in ANC or pH. In the Adirondacks, surface water ANC and pH both increased significantly in the 1990s, and toxic aluminum concentrations declined slightly. Regional surface water ANC did not change significantly in New England or in the Ridge/Blue Ridge.



Has the number of acidic waters changed? Modest increases in ANC have reduced the number of acidic lakes and stream segments in some regions. We estimate that there are currently 150 Adirondack lakes with ANC less than 0, or 8.1% of the population, compared to 13% (240 lakes) in the early 1990s. In the Upper Midwest, an estimated 80 of 250 lakes that were acidic in mid-1980s are no longer acidic. TIME surveys of streams in the northern Appalachian Plateau region estimated that 5,014 kilometers of streams (ca. 12%) were acidic in 1993-94. We estimate that 3,393 kilometers of streams, or 7.9%, remain acidic in this region at the present time. *In these three regions, approximately one-third of formerly acidic surface waters are no longer acidic, although still with very low ANC.* We find little evidence of a regional change in the acidity status of New England or the Ridge/Blue Ridge regions, and infer that the numbers of acidic waters remain relatively unchanged. There is no evidence that the number of acidic waters has increased in any region, despite a general decline in base cations and a possible increase in natural organic acidity.

Do changes in deposition translate into changes in surface waters? A major goal of this assessment is to evaluate the effectiveness of emission reductions in changing surface water chemistry. We only make this assessment for sulfate, because changes in the deposition of nitrogen have been minor. In New England, the Adirondacks and the Northern Appalachians, the percent declines in sulfate concentrations in precipitation were generally steeper than in surface waters. This is largely as expected, and suggests that, for a majority of aquatic systems, sulfate recovery exhibits a somewhat lagged response. However, the lakes and streams with the steepest declines in sulfate had very similar rates to those in deposition, indicating that the *most responsive* watersheds responded directly and rapidly to the sulfate decrease in deposition. As expected, there was little correspondence between rates of sulfate decline in streams and deposition in the Ridge and Blue Ridge provinces, due to the adsorptive capacity of the soils in the region. In the upper Midwest, the rate of decline in lakes was *greater than* the decline in deposition, probably reflecting the residual effects of the drought of the late 1980s. Longer term, we expect the chemistry of seepage lakes in the Upper Midwest to mirror the decline in deposition, similar to the pattern seen in seepage lakes in New England that did not experience the 1980s drought.

Complications for assessing 'recovery'. Declines in atmospheric deposition of sulfate have led to nearly universal declines in sulfate concentrations in surface waters. This response is one simple measure of the intended recovery in surface waters, and marks a success of the CAAA and efforts by industry in reducing SO2 emissions. However, the anticipated decrease in acidity corresponding to the decline in sulfate has been modest.

It is important to recognize that *recovery will not be a linear process*. Moreover, the changes in surface water chemistry reported here have occurred over very short periods relative to the implementation of the CAAA emission reductions in 1995. The decline in sulfate is without question due to the decline in emissions and deposition, but mechanisms producing other changes are much less clear. Other responses in surface waters may be partially attributable to factors other than atmospheric deposition, such as climate change and forest maturation. In particular, some of the observed increase in ANC may result from decreases in nitrate concentrations (e.g., in the Adirondacks and Northern Appalachian Plateau); changes in nitrate are unrelated to changes in nitrogen deposition, and are not expected to continue. If the trend toward lower nitrate in surface water reverses, some of the gains in ANC may be lost. We can identify at least five factors that are important in determining the recovery, or lack of recovery, in surface waters of the northern and eastern U.S. Continued long-term research and monitoring will be necessary to understand the causes, effects, and trends in these processes.

1) <u>Base cations</u>. We report declining surface water concentrations of base cations (e.g. calcium, magnesium) in all of the glaciated regions in this report (the Ridge and Blue Ridge region is the only non-glaciated region). At some individual sites, further acidification has occurred because base cations are declining more steeply than sulfate. While decreases in base cation loss from watersheds probably indicates slower rates of soil acidification, they none-the-less limit the magnitude of surface water recovery. Continued long-term research at acid-sensitive sites is needed to determine the cause

and effect of the relationship between base cations and sulfate, and the effects of cation loss on soil and surface water recovery.

2) Nitrogen. Continued atmospheric loading of nitrogen may be influencing the acid-base status of watersheds in yet undetermined ways. Unlike sulfate, concentrations of nitrogen in deposition have not changed substantially in 20 years. Also unlike sulfate, most nitrogen deposited from the atmosphere is retained in watershed soils and vegetation; nitrogen sequestration is not expected to continue *ad infinitum* (Stoddard 1994, Aber et al. in press). We report that surface water nitrate concentrations are largely unchanged, except in two regions characterized by high nitrate concentrations a decade ago (Adirondacks, Northern Appalachian Plateau). The mechanisms behind these decreases in nitrate are not understood, and could include climate change, forest maturation, and the effects of land-use history. Future increases in nitrate concentrations in all regions are not improbable, and would retard recovery if other factors remain constant.

3) Natural organic acidity. Increases in dissolved organic carbon in acid-sensitive waters may have contributed additional natural organic acidity to surface waters, complicating our interpretation of the response in acidity. This factor is an important long-term research question that is probably linked to complex issues including climate change and forest maturation.

4) Climate. Climatic fluctuations induce variability in surface water chemistry, and thus obscure changes that we expect to result from declining acidic deposition. Climate or climate-related processes may counteract recovery by producing declines in base cations to offset a decline in sulfate, or by inducing an increase in natural organic acidity. These interactions of factors underscore the need to continue monitoring a subset of sensitive systems so as to understand the full suite of drivers and responses in ecosystems.

5) Lag in response. Documentation of the response of watersheds to changes in atmospheric deposition may take longer than the timeframe of available data. Recovery itself may have an inherent lag time, beyond the time scale of currently available monitoring data. Moreover, the changes observed are not unidirectional. Uncertainty with respect to timeframes can only be resolved with continued long-term data.

Indicators of recovery. A main goal of the Title IV of the CAAA is to decrease the acidity of affected surface waters. Although decreases in acidity have occurred in several regions, additional factors appear to point toward recovery, *forecasting* an improvement in biologically-relevant surface water chemistry. It is not yet clear if further reductions in emissions and deposition will be necessary for widespread recovery to occur. These factors forecast the onset of recovery:

a) Sulfate is an increasingly smaller percentage of total ion concentration in surface waters.
b) ANC has increased modestly in three of the five regions.
c) Dissolved Organic Carbon has increased regionally, perhaps toward a more natural preindustrial concentration as acidity decreases in surface waters.
d) Toxic aluminum concentrations appear to have decreased slightly in some sensitive systems.

Expectations for recovery. An important consideration for measuring the success of the CAAA is to have appropriate expectations for the *magnitude* of potential recovery. Lakes inferred to have been measurably acidified by atmospheric deposition were already marginally acidic, typically with pH less than 6, before anthropogenic atmospheric pollution began more than 100 years ago. Therefore, full recovery of acidic lakes will not yield neutral pH. However, there is evidence that DOC will increase during recovery, and both increasing DOC and increasing pH values will lower the toxicity of aluminum. This change may allow recovery of fish populations to historical conditions even if pH remains low.

Recommendations. In the North and East, there is evidence of recovery from the effects of acidic deposition. The complexities of ecosystem response – effects of forest health, soil status, natural organic acidity, the relative importance of sulfur vs. nitrogen deposition, future emission/deposition scenarios – make predictions of the magnitude and timing of further recovery uncertain. The results of this trend analysis suggest two recommendations for environmental monitoring:

1) Deposition monitoring: The analyses in this report depended heavily on the long-term NADP/NTN program for monitoring the chemistry of precipitation. The future assessment of deposition and aquatic trends will depend heavily on these data, and therefore our recommendation is to maintain a national precipitation chemistry network.

2) Surface water monitoring: The effectiveness of current or future amendments to the Clean Air Act can best be determined by monitoring the response of subpopulations of sensitive surface waters through time. Long-term records provide the benchmark for understanding trends in ecological responses. The reviewers of early drafts of this report strongly urged the authors to recommend the continuation of the long-term research programs upon which this report is based, and the addition of biological monitoring to begin documenting potential biotic recovery.

Future research. The data from these long-term sites will be invaluable for the evaluation of the response of forested watersheds and surface waters to a host of research and regulatory issues related to acidic deposition, including soil and surface water recovery, controls on nitrogen retention, mechanisms of base cation depletion, forest health, sinks for sulfur in watersheds, changes in DOC and speciation of aluminum, and various factors related to climate change. As one reviewer of this report noted, *"these sites have irreplaceable long-term data that should constitute a 'research infrastructure' akin to an EPA laboratory. These sites will help address many basic science issues in which EPA ORD has a continuing interest."* Moreover, as several of the reviewers observed, long-term data serve as the foundation for ecological research and modeling. Without such data, our ability to ask the right questions is reduced, and our ability to base the answers to these questions on actual data is likewise compromised.

Appendix 5. Atlantic salmon (*Salmo salar*) rivers: A dynamic modeling approach

Thomas A. Clair[1], Ian Dennis[1], Peter G. Amiro[2], B.J. Cosby[3]

[1]Environmental Conservation Br, Environment Canada – Atlantic Region, PO Box 6227, Sackville, NB, E4L 1G6, Canada

[2]Science Branch, Fisheries and Oceans Canada, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS, B2Y 4A2, Canada

[3]Department of Environmental Sciences, University of Virginia, Charlottesville, VA, 22903, USA

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Abstract

Atlantic salmon populations have been extirpated from a number of rivers in Nova Scotia, Canada due to acid rain. We applied the Model of Acidification of Groundwater in Catchments (MAGIC) to 35 regional rivers to estimate pre-industrial water chemistry conditions, and the potential future changes in water chemistry under three acid deposition scenarios for the region. Our model results indicate that water chemistry in the study streams remained relatively unchanged until the 1950s, and reached their maximum effects on pH in the mid 1970s. The main effects of acid deposition have been a decrease in pH and an increase in base cations to surface waters, as the ion exchange processes in soils released soil cations into surface waters. We forecast future water chemistry in the rivers using three deposition scenarios: no change in sulface deposition from Year 2000, as well as 10% and 20% sulphate reductions per decade. We show that the more rapid the reduction in acid deposition, the faster recovery will be. We also show that although stream water acidity will recover within a few decades, in most streams, base cations will not recover to pre-industrial levels within the next 100 years.

Key Words: acid rain, Atlantic salmon, Nova Scotia, MAGIC

Appendix 6. Liming Aquatic Ecosystems – Tom Clair and Atlee Hindar

Liming aquatic ecosystems for acid rain mitigation: recent results and recommendations for the future

Thomas A. Clair[1] and Atlee Hindar[2]

[1]Environment Canada, P.O. Box 6227, Sackville, NB, Canada E4L 1G6
[2]Norwegian Institute for Water Research, Televeien 1, N-4890, Grimstad, Norway

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Summary

Our review shows that liming programs can be designed to improve water chemistry conditions of streams, rivers and lakes. When properly designed and consistently managed, a combination of liming and stocking programs will allow the recovery of targeted fish species in formerly acidified waters. However, research also shows that ecological recovery is not a straightforward process. Factors such as the presence of acid tolerant predators and availability of recolonizing species will affect the rate and direction of recovery.

We also show that, for many parts of Europe and North America, the recovery of soil and thus drainage waters from the effects of acidification will take decades to occur or not occur at all with planned emission reductions. This means that, in heavily affected areas, recovery of water chemistry and thus of aquatic ecosystems will take decades even under the most optimistic acid reduction scenarios. Such scenarios demand a long-term strategy for improving the ecological status in affected areas. We conclude that liming may be part of this strategy. Terrestrial liming has the broadest potential as it supplies the soil with base cations, thus counteracting the leaching of acid and toxic ions at the source. As any liming project considered in highly acidified regions will have to be undertaken for a long time, terrestrial liming provides the simplest way of achieving that goal.

In effect though, the ultimate goal of mitigation is the recovery of ecosystems to a “natural” state, and this can only be achieved through the cessation of acidification effects and the passage of time to allow soils and aquatic communities to recover. The real objective of any new mitigation program must be to keep further damage from occurring until the effects of pollution controls are reflected in catchment soils and therefore by drainage waters.